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ILLINOIS STATE ACADEMY OF SCIENCE

VOLUME XXII

Edited by H. C. Oesterling

TWENTY-SECOND ANNUAL MEETING

MACOMB, ILLINOIS

May 3 and 4, 1929

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A. R. CROOK, *Librarian*

State Museum, Springfield, Illinois

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ILLINOIS STATE ACADEMY OF SCIENCE

OFFICERS AND COMMITTEES FOR 1929-1930

President, M. M. LEIGHTON, State Geological Survey, Urbana.
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Second Vice-President, T. H. FRISON, State Natural History Survey, Urbana.
Secretary, A. C. WALTON, Knox College, Galesburg.
Treasurer, GEO. D. FULLER, University of Chicago, Chicago.
Librarian, A. R. CROOK, State Museum, Springfield.

The Council

The Council is composed of the above officers and the last two retiring presidents.

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MARJORIE SHANK, Southern Illinois Teachers' College, Carbondale.
DORR M. SIMER, 1660 N. College, Decatur.
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JOHN VOSS, 200 Dixon Avenue, Peoria.
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R. B. Miller, Department of Conservation, Springfield.
L. E. Sawyer, State Natural History Survey, Urbana.
A. G. Vestal, University of Illinois, Urbana.
C. E. Montgomery, State Teachers' College, DeKalb.
John Voss, Manual Training High School, Peoria.
Mary M. Steagall, State Normal University, Carbondale.

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W. H. Haas, Northwestern University, Evanston.
Jens Jensen, Landscape Architect, Ravinia.
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Committee on Legislation and Finance

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Edward W. Payne, First Trust & Savings Bank, Springfield.
H. C. Cowles, University of Chicago, Chicago.
F. H. Colyer, Southern Illinois State Teachers' College, Carbondale.

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The Secretary.
Fred R. Jelliff, Daily Register-Mail, Galesburg.

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Louis A. Astell, West Chicago Community High School, West Chicago.
H. H. Radcliffe, Night School, Decatur.
Rosalie M. Parr, University of Illinois, Urbana.
H. W. Garnett, Bloomington High School, Bloomington.

Delegate to the American Association for the Advancement of Science

A. C. Walton, Knox College, Galesburg.

Delegates to the Conservation Council of Chicago

W. G. Waterman, Northwestern University, Evanston.
V. O. Graham, University of Chicago, Chicago.

PAST OFFICERS OF ILLINOIS STATE ACADEMY OF SCIENCE

1907

(Organization meeting, Dec. 7, 1907, Springfield.)

Chairman, U. S. GRANT, Northwestern University, Evanston.
Secretary, A. R. CROOK, State Museum, Springfield.

1908

(First annual meeting, Decatur, Feb. 22, 23, 1908.)

President, T. C. CHAMBERLAIN, University of Chicago.
Vice-President, HENRY CREW, Northwestern University, Evanston.
Secretary, A. R. CROOK, State Museum, Springfield.
Treasurer, J. C. HESSLER, James Millikin University, Decatur.

1909

(Second annual meeting, Springfield, Feb. 20, 1909.)

President, T. C. CHAMBERLAIN, University of Chicago.
Vice-President, HENRY CREW, Northwestern University, Evanston.
Secretary, A. R. CROOK, State Museum, Springfield.
Treasurer, J. C. HESSLER, James Millikin University, Decatur.

1910

(Third annual meeting, Urbana, Feb. 18, 19, 1910.)

President, S. A. FORBES, University of Illinois, Urbana.
Vice-President, JOHN M. COULTER, University of Chicago.
Secretary, A. R. CROOK, State Museum, Springfield.
Treasurer, J. C. HESSLER, James Millikin University, Decatur.

1911

(Fourth annual meeting, Chicago, Feb. 17, 18, 1911.)

President, JOHN M. COULTER, University of Chicago.
Vice-President, R. O. GRAHAM, Illinois Wesleyan University.
Secretary, A. R. CROOK, State Museum, Springfield.
Treasurer, J. C. HESSLER, James Millikin University, Decatur.

1912

(Fifth annual meeting, Bloomington, Feb. 23, 24, 1912.)

President, W. A. NOYES, University of Illinois, Urbana.
Vice-President, J. C. UDDEN, University of Texas.
Secretary, FRANK C. BAKER, Chicago Academy of Science.
Treasurer, J. C. HESSLER, James Millikin University, Decatur.

1913

(Sixth annual meeting, Peoria, Feb. 21, 22, 1913.)

President, HENRY CREW, Northwestern University, Evanston.
Vice-President, A. R. CROOK, State Museum, Springfield.
Secretary, OTIS W. CALDWELL, University of Chicago.
Treasurer, J. C. HESSLER, James Millikin University, Decatur.

PAST OFFICERS OF THE ACADEMY—Continued.

1914

(Seventh annual meeting, Evanston, Feb. 20, 21, 1914.)

President, FRANK W. DEWOLF, State Geological Survey, Urbana.
Vice-President, H. S. PEPOON, Lake View High School, Chicago.
Secretary, E. N. TRANSEAU, State Normal School, Charleston.
Treasurer, J. C. HESSLER, James Millikin University, Decatur.

1915

(Eighth annual meeting, Springfield, Feb. 19, 20, 1915.)

President, A. R. CROOK, State Museum, Springfield.
Vice-President, U. S. GRANT, Northwestern University, Evanston.
Secretary, E. N. TRANSEAU, State Normal School, Charleston.
Treasurer, J. C. HESSLER, James Millikin University, Decatur.

1916

(Ninth annual meeting, Urbana, Feb. 18, 19, 1916.)

President, U. S. GRANT, Northwestern University, Evanston.
Vice-President, E. W. WASHBURN, University of Illinois, Urbana.
Secretary, A. R. CROOK, State Museum, Springfield.
Treasurer, H. S. PEPOON, Lake View High School, Chicago.

1917

(Tenth annual meeting, Galesburg, Feb. 23, 24, 1917.)

President, WILLIAM TRELEASE, University of Illinois, Urbana.
Vice-President, H. E. GRIFFITH, Knox College, Galesburg.
Secretary, J. L. PRICER, State Normal University, Normal.
Treasurer, H. S. PEPOON, Lake View High School, Chicago.
Librarian, A. R. CROOK, State Museum, Springfield.

1918

(Eleventh annual meeting, Joliet, Feb. 22, 23, 1918.)

President, J. C. HESSLER, James Millikin University, Decatur.
Vice-President, JAMES H. FERRISS, Joliet.
Secretary, J. L. PRICER, State Normal University, Normal.
Treasurer, T. L. HANKINSON, State Normal School, Charleston.
Librarian, A. R. CROOK, State Museum, Springfield.

1919

(Twelfth annual meeting, Jacksonville, March 21, 22, 1919.)

President, R. D. SALISBURY, University of Chicago.
Vice-President, ISABEL S. SMITH, Illinois College, Jacksonville.
Secretary, J. L. PRICER, State Normal University, Normal.
Treasurer, T. L. HANKINSON, State Normal School, Charleston.
Librarian, A. R. CROOK, State Museum, Springfield.

1920

(Thirteenth annual meeting, Danville, Feb. 20, 21, 1920)

President, HENRY B. WARD, University of Illinois, Urbana.
Vice-President, GEO. D. FULLER, University of Chicago.
Secretary, J. L. PRICER, State Normal University, Normal.
Treasurer, W. G. WATERMAN, Northwestern University, Evanston.
Librarian, A. R. CROOK, State Museum, Springfield.

1921

(Fourteenth annual meeting, Carbondale, April 29, 30, 1921.)

President, HENRY C. COWLES, University of Chicago.
Vice-President, CHAS. T. KNIPP, University of Illinois, Urbana.
Secretary, J. L. PRICER, State Normal University, Normal.
Treasurer, W. G. WATERMAN, Northwestern University, Evanston.
Librarian, A. R. CROOK, State Museum, Springfield.

1922

(Fifteenth annual meeting, Rockford, April 27, 28, 29, 1922.)

President, CHAS. T. KNIPP, University of Illinois, Urbana.
Vice-President, MISS RUTH MARSHALL, Rockford College, Rockford.
Secretary, C. FRANK PHIPPS, State Teachers' College, DeKalb.
Treasurer, WM. F. SCHULZ, University of Illinois, Urbana.
Librarian, A. R. CROOK, State Museum, Springfield.

1923

(Sixteenth annual meeting, Galesburg, May 3, 4, 5, 1923.)

President, W. S. BAYLEY, University of Illinois, Urbana.
Vice-President, W. G. WATERMAN, Northwestern University, Evanston.
Secretary, C. FRANK PHIPPS, State Teachers' College, DeKalb.
Treasurer, WM. F. SCHULZ, University of Illinois, Urbana.
Librarian, A. R. CROOK, State Museum, Springfield.

1924

(Seventeenth annual meeting, Elgin, May 1, 2, 3, 1924.)

President, W. G. WATERMAN, Northwestern University, Evanston.
Vice-President, H. J. VAN CLEAVE, University of Illinois, Urbana.
Secretary, C. FRANK PHIPPS, State Teachers' College, DeKalb.
Treasurer, WM. F. SCHULZ, University of Illinois, Urbana.
Librarian, A. R. CROOK, State Museum, Springfield.

1925

(Eighteenth annual meeting, Springfield, Feb. 20, 21, 1925.)

President, W. G. BAIN, St. John's Hospital, Springfield.
First Vice-President, C. H. SMITH, Hyde Park High School, Chicago.
Second Vice-President, R. C. LANPHIER, Springfield.
Secretary, C. FRANK PHIPPS, State Teachers' College, DeKalb.
Treasurer, W. B. MCDOUGALL, University of Illinois, Urbana.
Librarian, A. R. CROOK, State Museum, Springfield

PAST OFFICERS OF THE ACADEMY—Concluded.

1926

(Nineteenth annual meeting, Harrisburg, April 30, May 1, 1926.)

President, STUART WELLER, University of Chicago, Chicago.
First Vice-President, ELEANOR C. SMITH, Englewood High School, Chicago.
Second Vice-President, CLARENCE BONNELL, Township High School, Harrisburg.
Secretary, C. FRANK PHIPPS, State Teachers' College, DeKalb.
Treasurer, W. B. MCDOUGALL, University of Illinois, Urbana.
Librarian, A. R. CROOK, State Museum, Springfield.

1927

(Twentieth annual meeting, Joliet, April 29, 30, 1927.)

President, WILLIARD N. CLUTE, Editor, American Botanist, Joliet.
First Vice-President, MARY M. STEAGALL, Southern Illinois State Teachers' College, Carbondale.
Second Vice-President, C. E. SPICER, Joliet High School, Joliet.
Secretary, LYELL J. THOMAS, University of Illinois, Urbana.
Treasurer, W. B. MCDOUGALL, University of Illinois, Urbana.
Librarian, A. R. CROOK, State Museum, Springfield.

1928

(Twenty-first annual meeting, Bloomington-Normal, May 4, 5, 1928.)

President, H. J. VAN CLEAVE, University of Illinois, Urbana.
First Vice-President, C. FRANK PHIPPS, State Teachers' College, DeKalb.
Second Vice-President, R. H. LINKINS, Illinois State Normal University, Normal.
Secretary, LYELL J. THOMAS, University of Illinois, Urbana.
Treasurer, GEO. D. FULLER, University of Chicago, Chicago.
Librarian, A. R. CROOK, State Museum, Springfield.

1929.

(Twenty-second annual meeting, Macomb, May 3, 4, 1929.)

President, CLARENCE BONNELL, Harrisburg Township High School, Harrisburg.
First Vice-President, R. H. LINKINS, Illinois State Normal University, Normal.
Second Vice-President, FRED H. CURRENS, Western Illinois State Teachers' College, Macomb.
Secretary, LYELL J. THOMAS, University of Illinois, Urbana.
Treasurer, GEO. D. FULLER, University of Chicago, Chicago.
Librarian, A. R. CROOK, State Museum, Springfield.

ILLINOIS STATE ACADEMY OF SCIENCE

REPORT OF THE SECRETARY

Council Meeting, November 22, 1928, 1:30 p. m., Natural History Building, University of Illinois, Urbana

The entire new Council was present at the meeting called by President Bonnell. Dates for the annual meeting of the Academy in 1929 were discussed, and it was decided by vote to set May 3 and 4 as the most satisfactory dates and May 10 and 11 as alternative dates.

It was decided, also, that the character of the general sessions would be a symposium of the Archeology of Illinois, inasmuch as there are many splendid relics of ancient man and his work within easy access from Macomb, where the annual meeting is to be held, and leading authorities may be secured for presenting the subject to the Academy. A field trip to the Indian mounds near Lewiston was planned, and a trip through the ceramic industries in the vicinity of Macomb was also outlined.

As a matter of policy for the guidance of future meetings, the Council regards it as preferable that the individual members bear all the expenses of entertainment. This matter was brought out in a discussion with the Second Vice-President, Fred H. Currens, who is also chairman of the local committee, concerning the noon luncheon, May 3.

The Treasurer reports at this time that there has been a net gain of 40 new members since the annual meeting in May, 1928. He has, to date, invested $600.00 in first-mortgage bonds at six per cent. Cash on hand is $144.00.

The Secretary reports that Volume XXI of the Transactions has been in the hands of the printer for over two months and that there are prospects of publishing the volume around the first of the year.

Meeting adjourned.

(Signed) L. J. THOMAS, *Secretary.*

Council Meeting, May 3, 1929, 8:00 a. m., Museum of the Arts Building, Western Illinois State Teachers' College, Macomb

The meeting was called to order by President Bonnell. All members of the Council were present except George D. Fuller, W. N. Clute, and A. R. Crook. Vice-President Currens, Chairman of the local committee, was present and reported that if roads were too bad for the use of automobiles, hayracks would be used for the field trip from Lewiston to the Mounds. He stated, also, that a forty-cent lunch might be purchased at the hotel just before starting the trip, and that coffee would be obtainable at the Mounds.

The following delegates from affiliated societies reported present: M. M. Leighton, representing the Illinois Chapter of Sigma Xi; A. S. Galajikian, representing the Knox County Academy of Science; Mary M. Steagall, representing the Science Club of Carbondale; Paul K. Houdek, representing the Illinois Biology Teachers' Association; Miss Nimerscheid, representing the Egyptian Science Club; Marcia Snyder, Alma Shellenberger, Mary Faustino, and Helen Snyder, representing the Biology Club of Englewood High School.

There was a discussion of the affiliation policy, with reference to the limits of affiliation and the character of the affiliated societies. The Izaak Walton League was discussed. Article V of the Constitution was cited by the Secretary as indicating that affiliation was limited to scientific societies. By vote this matter was referred to a conference with the Chairman of the Affiliation Committee. The subject of joint meetings with affiliated societies was brought up and advantages mentioned, and attention was called to the joint meeting of the newly organized Junior Academy of Science.

An editorial policy for the Transaction was discussed, but no action was taken. Also the matter of splitting the office of the Secretary and Editor was suggested by the Secretary because of the increased burden produced by the steady growth in membership and the size of the Transactions. By vote it was decided to refer these items of business to the new Council.

The next business in order was that of the need for the adoption by the Academy of a definite financial policy. It was moved and seconded that the Council confirm the action of the present Treasurer in investing the surplus in bonds. By vote of the Council the Treasurer was authorized to establish a *permanent*

fund, only the interest of which may be used. The permanent fund, as outlined by the Secretary, is to consist of (1) life membership dues, (2) donations, (3) and such funds as the Council may see fit from time to time to add from accumulations in the treasury. It was suggested by the Secretary that this policy of establishing a permanent fund be brought to the attention of the members of the Academy and that it be proposed for incorporation as a by-law in the Constitution at the next annual meeting.

On motion by C. T. Knipp, it was voted that the subject of affiliation of non-scientific societies be carried over for investigation for another year and that a definite policy be adopted.

The meeting then adjourned to the Main Auditorium for the General Session of the Academy.

(Signed) LYELL J. THOMAS, *Secretary.*

General Session of the Academy, May 3, 1929, Auditorium, Main Building, Western Illinois State Teachers' College, Macomb

President Bonnell opened the meeting at 9:00 a. m. and introduced Prof. W. P. Morgan, President, Western Illinois State Teachers' College, who gave a warm welcome to all those individuals and organizations assembled at Macomb, in the interests of science. President Bonnell then delivered his address on "The Academy's Opportunities for Usefulness," which in turn was followed by several addresses comprising a *Symposium on the Archeology of Illinois,* as follows:

"Cultural Affinities and Differences in Illinois Archaeology," by Warren King Moorehead, Director of the Department of Archaeology in Phillips Academy, Andover, Massachusetts; and Director of Archaeological Explorations for the University of Illinois, 1921-1929.

"The Use of Animal Life by the Mound-building Indians of Illinois," by Frank Collins Baker, Curator of the Natural History Museum of the University of Illinois.

"Geology and the Indian Mounds," by M. M. Leighton, Chief of the Illinois State Geological Survey, Urbana.

"Methods of Determining Prehistoric Chronology," by Melville J. Herskovits, Department of Archaeology, Northwestern University, Evanston, Illinois.

"The Fisher Mound and Village Site," by George Langford, McKenna Process Company of Illinois, Joliet (Presented by Fay-Cooper Cole, University of Chicago).

After the presentation of Mr. Langford's paper Professor Cole stressed the need of public aid and support in preventing the destruction of Indian mounds and in suppressing vandalism, also the part the intelligent layman could play under proper guidance, as illustrated by Mr. Langford's work and that of the Dickson brothers whose excavations were to be visited the following day.

Business Meeting of the Academy
11:30 a. m., May 3, 1929

At the conclusion of the symposium, the regular business meeting of the Academy was held in the same room, and the following reports of officers and committees were presented in order, as called for by President Bonnell.

In the absence of the Treasurer, the Secretary read the following report:

REPORT OF THE TREASURER

FOR YEAR ENDING APRIL 20, 1929

Receipts

Balance on hand April 20, 1928	$197.29	
Initiation fees and dues	620.00	
Received for reprints of articles	128.57	
Received for sale of Transactions	21.00	
Allowance from A. A. A. S. on dues	332.00	
Received interest	37.25	
Protested cheque made good	3.29	
Total receipts		$1,339.40

Expenditures

Expenses of 1928 meeting:			
Programs, postage, etc.	$99.07		
Expenses of Secretary and Treasurer	37.12		
Stenogr., telegrams, etc.	14.43		
Honorarium for speaker	20.00		
Illini Coach, field trip	32.50		
		$203.12	
Mailing Transactions		80.00	
Stationery for 1928-29		34.00	
Printing reprints of articles		120.07	
Expenses of Secretary's office		147.43	
Expenses of Treasurer's office		77.00	
Expenses of Council meetings		10.74	
Mortgage Bonds and interest		304.15	
Secretary's salary		150.00	
Proofreading of Transactions		35.50	
Protested cheque		3.29	
Total expenditures			$1,165.30
Balance in University State Bank			174.10
			$1,339.40

Statement of resources in Treasurer's hands April 20, 1929

Balance in University State Bank	$174.10
Mortgage Bonds	800.00
Accrued interest	4.50
Office supplies, estimated	15.00
Total	$993.60

(Signed) GEO. D. FULLER, *Treasurer.*

As the Auditing Committee had already been appointed by the President, the Secretary read the following report:

We, the committee appointed to audit the report of the Treasurer of the Illinois State Academy of Science, have examined the accounts, which appear to have been correctly kept, and have verified the entries of expenditures against approved vouchers made by the President and the Secretary. We find the cash balance of $174.10 and the Mortgage Bonds of $800.00 as reported April 20, 1929, to be correct.

Chicago, Illinois,
April 30, 1929. (Signed) A. C. NOE'
JOSEPH B. HAWKES
HENRY C. COWLES

The above report of the Treasurer and the Auditing Committee was approved and accepted by vote of the members present.

REPORT OF THE PUBLICATION COMMITTEE

One thousand copies of Volume XXI of the Transactions of the Illinois State Academy of Science, edited by the Secretary, were printed, and a copy was mailed to each member by the Librarian April 10, 1929. Reprints of articles ordered by authors have not been received from the printers to date, but will soon be ready for delivery, and a notice and statement of amount due will be sent to each author.

Twelve hundred copies of the Preliminary Program and one thousand copies of the Final Program of the Twenty-second Annual Meeting, prepared and arranged by the Secretary, were sent out before the meeting to members of the Academy, societies affiliated with the Academy, local committeemen, newspapers, and high schools and normal schools of the state.

One thousand copies of a small pamphlet prepared by the Secretary, setting forth the character and aims of the Illinois State Academy of Science, and including a form to be used in making application for membership, were also distributed.

(Signed) LYELL J. THOMAS, *Chairman.*

The above report of the Publication Committee was accepted and approved by vote of the members present.

REPORT OF THE MEMBERSHIP COMMITTEE

In the absence of Mrs. Eleanor Smith, Chairman, the report was made by Dr. Vida A. Latham, naming 72 new members for election, 8 deceased, 9 resigned, and 38 dropped because of three years arrears in dues, making a net gain of 33 members for the year.

This report was approved and accepted by vote of the members present, and the new applicants for membership were elected at this time. [See list of members at the end of this volume.]

REPORT OF THE COMMITTEE ON ECOLOGICAL SURVEY

E. L. Stover, Chairman, presented an elaborate report covering the work of the Committee as proposed in their report of May 4, 1928, consisting of a Bibliography of Ecological Literature on Illinois Flora and Fauna. This report was voted accepted.*

REPORT OF THE COMMITTEE ON CONSERVATION

In the absence of the Chairman the following report was read by the Secretary:

State Parks.—There has been much activity recently in the Department of Public Works and Buildings in connection with the acquirement of new state parks. The most important new acquirements are: (1) the Blackhawk State Park, Rock Island County, 200 acres; (2) White Pine Forest Park, Ogle County, 290 acres; (3) Giant City Park, Jackson County, 400 acres; (4) Buffalo Rock Park, LaSalle County; (5) Pierre Menard Homestead and Fort Gage, 32 acres. Buffalo Rock Park was given to the state by Richard T. Crane, Jr. and is valued at 100 thousand dollars. It is hoped that this splendid gift will stimulate others to do likewise. The Pierre Menard Homestead and Fort Gage are of much historical interest and well worth acquirement by the state. There is a bill in the present legislature for the acquirement of dune land north of Waukegan as a state park. This is a splendid bill and should receive good support. It is the only chance the state has to acquire a park on the shore of Lake Michigan.

State Forests.—Unfortunately the State has been hampered in the acquirement of state forests, not because of any laws prohibiting such acquirement but because certain unfortunate features have interfered with the excellent plans that the state forester and others have prepared. The Department of Conservation, under which the state forestry work is largely conducted, has acquired

* The Secretary suggests that because of the character of this report it be issued as a separate publication.

about five thousand acres of land, the largest tract being Horseshoe Lake, a tract of 3,100 acres, serving more as a game refuge than a forest, although there is much forest land in the tract. There is still hope that some forest land may be acquired specifically, prior to July 1st. The Department of Conservation has also acquired some three thousand additional acres for shooting grounds, game refuges, fish hatcheries, etc.

(Signed) HENRY C. COWLES, *Chairman.*

The above report was approved.

REPORT OF THE COMMITTEE ON FINANCE AND LEGISLATION

Pursuant to the instructions given at the last annual meeting, your Committee on Legislation has labored to secure the passage by the present Legislature of a bill to prevent the pollution of Illinois streams and lakes. Two bills, the Jewell and the Ickes, have been presented, the Jewell in the Senate and the Ickes in the House. The Jewell bill passed the Senate without a dissenting vote, and then went to the House. On Wednesday the House committee reported the bill favorably to the House, and it is now before that body for action. Besides our own organization, the Illinois Division of the Izaak Walton League and agricultural interests are supporting the measure. We recommend that the Academy now urge passage of the Jewell bill, which at present seems to have the best chance of passage, and that, if it fail, support of the Ickes measure be asked.

Your committee is informed that appropriations for the State Museum, the Geological Survey, and other scientific work in the various departments will be of a satisfactory nature.

There have been presented to the Legislature eight measures affecting game, and affording greater protection to fur-bearing animals, safeguards for mussels, frogs, turtles, fish, and deer, and providing a closed season for rabbits.

Of scientific interest are the ten bills for flood relief of various streams, and for the improvement of the Illinois River.

Affecting conservation are eight measures, some in the Senate and some in the House. The Governor is authorized, by one bill, to designate a conservation day in spring. Senator Jewell's bill to force owners of stripping mines to restore the land to a level condition was defeated in committee. Senate Bill 232 creating a uniform conservation, forestry, fish, and game commission to investigate and report to the next Legislature uniform laws on conservation, is an important measure. Other measures provide for the creation and management of forest preserve districts, for a scheme of state-wide recreational and conservation areas, calling for a bond issue of $14,000,000, to be submitted to popular vote, for water conservation, and for the acquisition of the Dunes area for park purposes, which last is in the hands of a sub-committee of the Senate.

(Signed) FRED R. JELLIFF, *Chairman.*

This report was approved and accepted by vote of the members present.

In the absence of Professor Ward, the Secretary gave a brief of the contents of the following report, because of the lateness of the hour and the length of the extract.

REPORT OF THE DELEGATE TO THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Extract from the First Communication, 1929, Minutes of the New York Session, December 27, 1928.

The New York session of the Academy Conference was called to order by Mr. William H. Alexander, of the Ohio Academy of Science, Chairman of the Conference for 1928. The session was held in the library of the Lincoln Hotel, following the first council session of the fifth New York meeting of the Association, December 27, 1928.

The following representatives were present at the meeting:

William H. Alexander (chairman), Ohio Academy.
Howard E. Enders (secretary), Indiana Academy.
William M. Brown, Virginia Academy.
Bert Cunningham, North Carolina Academy.
Wright A. Gardner, Alabama Academy.
Chancey Juday, Wisconsin Academy.
Burton E. Livingston, A. A. A. S. as a whole.
John T. McGill, Tennessee Academy.
Grover C. Mance, South Carolina Academy
D. W. Morehouse, Iowa Academy.
Peter Okkelberg, Michigan Academy.
Aven Nelson, Colorado-Wyoming Academy.
A. F. Ortenburger, Oklahoma Academy.
John L. Tilton, West Virginia Academy.
Henry B. Ward, Illinois Academy and A. A. A. S. as a whole.

Chairman Alexander reported on the correspondence regarding the method of electing officers, stating that the concensus of opinion favored the suggestion that the secretary of the Conference automatically become the chairman for the succeeding year. On motion the report was adopted and the election approved on the basis of the circularized vote. Accordingly Dr. Howard Enders, Indiana Academy, became chairman of the Conference for 1929 and D. W. Morehouse, Iowa Academy, was elected secretary for 1929.

Marcus W. Lyon, Indiana Academy, presented a very interesting paper on membership in State Academies, calling attention to the fact that teachers of science in high schools do not become members of their respective state academies. He presented several arguments why they should and called attention to the prevailing alibis of the high school teachers. He emphatically urged that high school libraries should have publications on science and called attention to the surprising fact that few high school libraries take *Science, Science News-Letter*, or similar magazines. He stated that only twenty-four states

are represented in the American Association for the Advancement of Science. The publication of a bulletin was urged as a proper means of getting material before the science workers.

An interesting and helpful discussion followed the presentation of the paper. William H. Alexander, Ohio Academy, strongly urged that we impress upon the science teacher the fact that to become a member of a state academy of science is an honor and that he is joining an important body.

Grover C. Mance, South Carolina Academy, spoke of his experience in getting members to join the South Carolina Academy of Science, indicating what personal attention would accomplish.

John L. Tilton, West Virginia Academy, called attention to the fact that this is an age of commerce and not science, an age of pedagogy and not content. He pointed out the necessity of a better preparation of science teachers.

Henry B. Ward, Illinois Academy, spoke of the strength of State Academies in the West and their influence in developing a spirit of science, urging the co-operation of the various state academies through the medium of the American Association for the Advancement of Science.

Burton E. Livingston, permanent secretary of the American Association for the Advancement of Science, explained that the Association could circularize the science workers of any state from the Washington office as if the circularization were coming from the Academy itself. He pointed out that it could be done much less expensively through the Washington office.

John T. McGill, Tennessee Academy, explained the importance of distributing the meeting places of the State Academies throughout the state, thus stimulating interest in the Academy.

William M. Brown, Virginia Academy, called attention to the Virginia law stating that science teachers are required to have a minimum of two years of science.

Chairman Enders urged that the information be gotten from the presidents and secretaries of each state concerning the funds available for publication, also the method of securing members. It was urged that this information is not for standardization but to learn what each state is doing.

Chancey Juday, Wisconsin Academy, spoke on state aid for Academies of Science. Wisconsin publishes two volumes in three years. It has a library which is housed in the State University and that there are seven hundred exchanges.

Burton E. Livingston, permanent secretary of the A. A. A. S., offered to circularize teachers of the states for membership. The offer was accepted with enthusiasm and Dr. Livingston given a vote of thanks for the courtesy.

Upon motion the meeting adjourned to attend the annual complimentary secretaries' dinner, given by the American Association for the Advancement of Science.

(Signed) HENRY B. WARD, *Delegate.*

This report was approved by a vote of the members present.

Because of their absence no report was given by the delegates to the Chicago Conservation Council.

The President appointed the following committees to report at the final business meeting, 5:00 p. m., Auditorium, Main Building:

Auditing—Fred R. Jelliff, Chairman; C. T. Knipp; Paul Houdek.

Nominations—A. C. Noé, Chairman; Thomas G. Hull; George Langford; Theodore Frison; Mary M. Steagall.

Meeting adjourned until 5:00 p. m.

Many members purchased their lunch at the cafeteria on the campus so as to be present at the opening of the section meetings at 1:45 p. m.

(Signed) LYELL J. THOMAS, *Secretary.*

Final Business Meeting, May 4, 1929

At 5:00 p. m. the final business meeting was called to order in the Auditorium of the Main Building. Thirty-one active members of the Academy were present at this meeting. The following reports were received:

REPORT OF THE RESOLUTIONS COMMITTEE

The following resolution on *Calendar Simplification* was submitted to the Committee on Resolutions by A. R. Crook:

In 1913, again in 1926, and in 1928, the Illinois State Academy of Science* appointed committees on calendar reform and passed resolutions requesting legislators to take action looking towards calendar simplification. We are encouraged to note that in Congress the chairman of the House Committee on Foreign Affairs, Representative Porter, has called into council a national committee on calendar reform, which is headed by George Eastman of Rochester and contains representatives of the National Academy of Science, the U. S. Naval Observatory, the U. S. Almanac, the U. S. Weather Bureau, the U. S. Department of Labor, the Inter-State Commerce Commission, the U. S. Chamber of Commerce, etc.

This committee favors House Joint resolution number 334 proposing participation by the United States in an International Conference on Simplication of the Calendar.

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* Transactions, Volume VI, p. 15; Volume XIX, p. 22; Volume XXI, p. 14.

The American Association for the Advancement of Science has expressed itself as in favor of calendar simplification and has appointed the following committees:

W. W. Campbell, University of California.
A. R. Crook, Illinois State Museum.
Gano Dunn, New York City.
C. F. Marvin, U. S. Weather Bureau.
A. E. Kennelly, Harvard University, *Chairman.*

Resolved that, since there is general agreement that the interests of business, science, and other forms of human activity will greatly benefit by calendar improvement, the Illinois State Academy of Science again urges our law makers to take steps which will advance the reform. We believe that the best science as well as the best business would lead to the adoption of a calendar of 15 months with an extra New Years day with no week day name at the end of the year and a leap day once in four years at the middle of the year.

The above resolution was approved and accepted by vote of the members present, and the following resolutions were then read:

Resolved, that the State Academy of Science reaffirms its previous declaration that the pollution of the streams and lakes of the State by sewage and factory waste is a disgrace and constitutes a menace to the health and well-being of the people of the State, in that it renders the water unfit for farm and recreational and municipal purposes, and that it tends to destroy fish life, and that we urge the passage of the Jewell bill now pending in the House and designed to abate and prevent this evil.

Resolved, that the secretary be authorized to transmit immediately this action to the House.

Resolved, that the Illinois State Academy of Science learns with deep regret of the deaths of Dr. T. C. Chamberlain, head of the department of geology of Chicago University, and former president of the Academy, and of Dr. John M. Coulter, head of the department of Botany of Chicago University and also a former president of this Academy, that we recognize the large and illustrous service which they rendered science, that we cherish the memory of their fine personal qualities, and that the Academy of Science in their deaths has suffered a distinct loss. Resolved, that the Secretary be instructed to place this testimonial in the records and also send it to the families of the deceased.

Resolved, that the Illinois State Academy of Science notes with sadness that death has been busy in its ranks the last year, and desires to have placed in its record its appreciation of the scientific work and attainments of the following who have died during the year: Truman W. Brophy, D. C. Davies, R. A. Gantz, Dr. J. S. Kauffman, Daniel Lichty, J. B. MacLeod, M. P. Somes.

Resolved, that the Illinois State Academy of Science is deeply grateful to the Western Illinois State Teachers' College, to F. H. Currens and the local committee on arrangements, whose efforts have so largely contributed to the success of our meeting, to the Chamber of Commerce for transportation for the field trip, to the press for its generous aid, and to all others who have in any way aided to make the gathering enjoyable and memorable.

Resolved, that the Academy expresses its deep appreciation for the faithful and efficient work that its officers have done during the past year.

(Signed) FRED R. JELLIFF,
CHAS. T. KNIPP,
P. K. HOUDEK.

The above resolutions were approved and accepted by the vote of the members present.

REPORT OF THE NOMINATIONS COMMITTEE

The report of the Nominations Committee was read. It was moved and seconded that the Secretary cast a ballot for the nominees. Passed. The following is the result:

Officers for 1929–1930

President—M. M. Leighton, State Geological Survey, Urbana.

First Vice-President—Fred R. Jelliff, Daily Register-Mail, Galesburg.

Second Vice-President—To be appointed by the Council.

Secretary—A. C. Walton, Knox College, Galesburg.

Treasurer—George D. Fuller, University of Chicago, Chicago.

Committees for 1929–1930

Third member of the Publication Committee—Fred R. Jelliff, Editor, Daily Register-Mail, Galesburg.

Affiliation Committee, reëlected.

Membership Committee, to be appointed by the Council.

Ecological Survey Committee, reëlected with the exception of Samuel Eddy and W. B. McDougall. The two new members elected were A. R. Kienholz, University of Illinois, and W. C. Allee, University of Chicago.

Conservation Committee, reëlected with the exception of W. N. Clute who is now out of the state. It was left to the Council to appoint a member to replace Mr. Clute.

Committee on Legislation and Finance, reëlected.

Committee on High School Science and Clubs, reëlected.

Librarian, reëlected.

Henry B. Ward was again appointed as delegate to the A. A. A. S. which meets in Des Moines, Iowa.

The Secretary entered a plea for the separation of offices of Secretary and Editor of the Transactions and called attention to the need of the Secretary giving more time to promoting membership. It was pointed out that the editing of the Transactions is a job in itself. He also entered a personal word of appreciation for the splendid cooperation of F. H. Currens as Chairman of the Local Committee and for the work of Miss Bennett in taking charge of the registration.

A rising vote of thanks was given to the Secretary for his work in the interest of the Academy.

M. M. Leighton extended an invitation to the Academy to meet at Urbana next year and mentioned the joint meeting possible because of plans of the State Geological Survey for its quarter-centennial celebration to be held there in May.

Arthur L. Epstein presented an invitation from Peoria for the next annual meeting to be held there but stated that Peoria would defer it in favor of Urbana.

A. C. Noé extended an invitation to the Academy to meet at the University of Chicago but stated that they would defer it a year in favor of Urbana because of the Geological Survey's plans.

These invitations were voted to be considered by the New Council.

The meeting then adjourned.

(Signed) LYELL J. THOMAS, *Secretary.*

New Council Meeting, May 5, 1929, 8:00 a. m., Lamoine Hotel, Macomb

President Leighton called the meeting and directed the attention of the members to the following items of business.

The place of meeting, Urbana, was provisionally selected, pending the sanction of President Kinley of the use of buildings at the University of Illinois.

By vote of the members present the Council temporarily established the office of Editor of the Transactions of the Illinois State Academy of Science at a salary not to exceed the sum of $75.00 and empowered the President, in consultation with the Secretary, to employ a competent person for this office. It was also voted that the Secretary furnish the President with memoranda concerning the committees and officers yet to be appointed.

The Council voted to confirm the financial policy adopted by the preceding Council.

It was proposed that an honorarium of $25.00 each be granted Professor Fay-Cooper Cole and to Professor Warren K. Moorehead as a token of appreciation by the Academy for their cooperation in making the symposium a success. This was approved by vote of the Council.

It was also voted by the Council that the Secretary be instructed to transmit a letter of appreciation to the Dickson brothers in behalf of the Academy for the cordial hospitality extended to members at the excavations.

(Signed) LYELL J. THOMAS, *Acting Secretary.*

PAPERS PRESENTED IN GENERAL SESSION

THE ACADEMY'S OPPORTUNITIES FOR USEFULNESS*

CLARENCE BONNELL
Township High School, Harrisburg.

With a program so full and interesting as we have before us this morning it certainly would not be fair for your presiding officer, however important his message might be, to take much time in fulfilling the constitutional requirement that he "prepare an address which shall be delivered before the Academy at the annual meeting."

The objects which justify the existence of this organization are stated in Article II of its constitution as follows: first, the promotion of scientific research; second, the diffusion of scientific knowledge and spirit; and, third, the unification of the scientific interests of the state.

The Academy has done much toward accomplishing these aims. It has always made progress. Yet, some of our friends fail to join us, for reasons which they deem adequate, and still others remain indifferent.

If we have, to use the phraseology of another, any "frozen assets," or if we are letting any opportunities for usefulness drift by, it is worth a few minutes of our time to take stock of our assets and liabilities. Our neglected opportunities, if we have any, may be termed our liabilities. Our liquid assets are our accomplishments. Our "frozen assets," if such exist, are our unproductive accomplishments, and they may be turned into liabilities if we do not liquidate them. If your speaker fails to find any real liabilities, other members may at least be stimulated by the thought and so find them or take steps to see that there shall be none in the future.

The first account on the ledger is headed "promotion of scientific research." To our credit, it may be said that we have stood, and shall stand in the future, for better support of, and better facilities for, research in our great centers of learning and in-

* Address of the retiring president.

dustry where the patient worker in either pure or applied science must necessarily carry on the greater part of his labors. Many of our present and former members are men and women whose discoveries in science are known the world over. These leaders of scientific thought attend our meetings and appear on our programs. They encourage the isolated worker with his little problems. It is significant that the Council of the Academy at the meeting at Galesburg six years ago had this item in the minutes of its proceedings: "It was the opinion of the Council that the section chairmen should be asked to secure papers for the annual meeting from high school teachers and from those beginning research work, and not so many as in recent years from university research professors."

And before that time President Bayley in a letter to me asking that I arrange the biology program for that meeting, had said: "I hope you will emphasize the importance of having papers by young workers rather than by those of more experience."

Any searcher after Nature's truth may bring his report to our meeting, read his paper, and have it published in the Transactions of the Academy if it has merit. We get some chaff but would lose some good grain if the fan blew all the light stuff away. These grains that are thus saved may make the by-product whose value will give a balance on the credit side of our ledger.

Personally, your president believes that every program should have on it just as many names as possible of the best men and women from the colleges and universities. We should search out, also, men and women of scientific instincts who are not aware of the opportunities to receive encouragement and help from the Academy. Men are certainly making discoveries in the industrial plants in such places as LaSalle, Chicago, Granite City, Rockford, Springfield, and Macomb. Their discoveries may not be of direct application to the industry itself and so go unnoticed. Some of these men know no way and have no way of publishing their findings. It might be worth the effort if the Academy could establish a closer connection with the hundreds of industrial plants and their workers to the end that guidance and encouragement could be extended. Efforts have been made by the writer to interest farm bureau agents and through them some farmers and horticulturists in the hope that the Academy might help them and be benefited by such co-operation, but without success. This is a thing that could be done with proper combination of efforts.

A large number of our members are teachers. Some are high school instructors, but they represent only a small fraction of the total number in the state. High school teachers of science are supposed to have learned the method of research and to have been inspired with the spirit of investigation before leaving the university.

Six years ago, in connection with the program mentioned before, I wrote to more than a hundred high school teachers who had attended the Biology Section of the High School Conference at Urbana the previous November and who were not then members of the Academy. They were asked whether they had been making any investigations outside their class work which would be of any interest to the Academy. About sixty replied, for they were virtually being asked to join the organization and to contribute to the program. Some few joined the Academy, but only one of the sixty indicated that anything was being done in research. His was a case of the spirit being willing and the flesh weak, for his investigations were not completed and he was not secured for the program. His subjects of research were:

1st. The History of Evolution.
2nd. Instinct and Reason.
3rd. The Future of Our World and Its Species.
4th. The History and Future of Man.

Would it not be worth while for the Academy to try to wield a greater influence than has been done heretofore to direct toward definite objects of research this little army of teachers all of whom have had some training in scientific ways of thinking? It is true that the facilities for research in isolated situations are very different from those in the university or the great industrial laboratory. But, there are often other facilities that need only the mind of a director and the hand and brain of an eager worker to make some lonely spot a laboratory.

Whether the Academy could set up problems and direct their solution through a committee which could function in the out-of-the-way places that are not now called laboratories, is a question for those more expert in such matters than I. Would it not be possible for our committees on Conservation and Ecological Survey to enlist this aforementioned army and with it a still greater army of high school students? Even though the rank and file were only gatherers of material, such a host, if they could be enlisted, might be directed by competent leaders to have such a thirst for the unknown and to spread such a spirit of original

discovery that the average man of the street would no longer think of the research worker in his laboratory as a hermit set apart from his fellow men.

The second account on our ledger has to do with "diffusion of scientific knowledge and spirit." Here, again, we have much on the credit side of the ledger. Specialists bring to us at our annual meetings the results of years of study. I know of no other meeting in the state where the astronomer may learn from the chemist, the physicist from the biologist, the geologist from the doctor of medicine, as can be done here. This is especially true on our field trips. Men of much learning in one field explain in clear but simple terms to men of equal learning in other fields what to one is commonplace and to the other something new, while those of us who are not specialists in any field are imbued with the spirit of scientific knowledge if not with the substance. I prize a small picture of an ex-president of the Academy taken as he was earnestly trying to learn of a woodsman the almost lost art of splitting clapboards. This picture is typical of the spirit of science. The humble spirit to learn is perhaps of as much value as what we do learn at these meetings. Those who reside at the seats of learning cannot appreciate the stimulation that comes to the less-favored few of us who attend these meetings, often to add but little to the discussion ourselves but to take away that enthusiasm that comes from getting first-hand information while it is yet new. The fact that many of the papers given here are published in scientific journals and that there is a steady, though limited, demand for copies of the Transactions, indicates that scientific knowledge and spirit are being diffused.

Sometimes, before such knowledge has reached the average man of affairs who would appreciate it and profit by it, it has become too diffuse, if not fogged. In other words, too much scientific knowledge never gets to the ultimate consumer with full weight and unadulterated. This is a difficult thing to remedy, and perhaps not within the province of the Academy to approach directly. We are not in close enough contact. The local papers sometimes surround us with an air of mystery by quoting all the long technical titles from our program and leaving the others out. True, some of our papers are, and must be, highly technical. They might be given simpler names and thus dispel some of the fog. The tendency seems to be toward greater simplicity in wording wherever truth and accuracy of statement will not be sacrificed.

The technical language of the paper is, sometimes, inversely proportional to the learning of its author. Most of our speakers are clear and easily followed. Their papers are models of simplicity as compared with the attempts of the average business or professional man to talk about his chief interests before a high school audience. Frequently, medical and dental societies and welfare organizations, seeking to diffuse specially applied, up-to-date, practical knowledge to patient and long-suffering groups of high school students, send out men who can neither express themselves clearly nor entertainingly.

It would be a boon to multitudes of knowledge-hungry, common folks if there were professional men and women and more people trained in science who could talk more clearly and entertainingly. We need fewer so-called scientific writers for the Sunday papers and fewer lyceum lecturers on science who startle but do not inform, and more people of the type of Louis Agassiz who could draw the thousands to his lectures by his personal magnetism and his commonplace elucidation of his subject. So much is said in the name of science which even the novice knows is untrue, that the untrained but intelligent man does not know what or whom to believe. And so the fog gathers. In this age of radios and automobiles there are yet many who will go to hear the man of science if he is known to be an authority and can tell his story well. It is up to us as individuals to frown upon fakes and pretenders of all sorts and to support measures that tend to suppress them. It is also up to us to be anxious and, yea, even prayerful, that we know the truth and dare maintain it, and that we train ourselves, if we do not already have "the gift of tongues," so that when we speak "the wayfaring man, though a fool, shall not err therein."

How many of our scientific assets are "frozen" because so many learned ones cannot diffuse their knowledge! The late Robert Ridgway, in a whimsical mood, wrote to me the following a few years ago: "As to reading a paper or delivering a speech at the meeting of the State Academy of Science, I will say that many years ago when a very small boy, I stood up in school to recite 'Twinkle, twinkle little star.' I got exactly that far when my confidence gave way to stage fright, and I have never since had the courage to try it again." What a boon to himself and especially to the rest of us it would have been if this timidity could have been overcome!

That the Academy is in hearty accord with this second object of its endeavor is evidenced by the fact that though it has had among its twenty former presidents such men as Chamberlain, Coulter, and Weller and others living and dead whose names all stand for much in science, it has honored one with that office whose only claim to distinction is in the diffusion of scientific knowledge and spirit. It has been to me a rare privilege to be permitted to hold one position as teacher, for twenty-five years in a remote but growing community, there to have a little part in inspiring in the hearts of many hundreds of young people and scores of adults an appreciation of the wonders about them and in making their place under the sun a little more delightful by some knowledge of science.

"The unification of the scientific interests of the state," is the third account on our ledger. Here, we have made progress in recent years. Scientific organizations in the state are not numerous. Some of the new ones have been brought into existence partly through the influence of the Academy and are now affiliated. There are enough people in every ten counties in the state outside of Cook county to support a science club similar to the Egyptian Science Club, the one with which I am most familiar. The time may be near when the Academy may need a secretary for the affiliated societies whose business it will be to keep them in close touch with the main organization. Such a need will come before all the possible organizations of such a nature shall have been perfected. The Academy should look forward to the time when the scientific interests of the state are united into a well-articulated whole, each part of which functions alone and along its particular line but works together with the other parts for the common good.

CULTURAL AFFINITIES AND DIFFERENCES IN ILLINOIS ARCHAEOLOGY

WARREN KING MOOREHEAD
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Director of Archeological Explorations for the University of Illinois.

That portion of the earth's surface which we now designate as the State of Illinois played an exceedingly important part in prehistoric times. One may safely assume that the region lying between the Ohio and Lake Michigan, the Mississippi and the Wabash, offered special attractions to Neolithic man. Not only was there an inexhaustible supply of game, but the Illinois country was in a strategic position. To the west lay the great buffalo country. There was direct contact by water with many distant tribes. No region—not even Ohio, famous in Indian times—could be traversed by canoe more easily. The streams were not obstructed by falls, and there were no mountain ranges. To the west lay two great rivers, the Mississippi and Missouri; toward the south the Ohio and Tennessee-Cumberland—all penetrating thickly populated Indian communities. This favorable setting can not be exceeded elsewhere in North America.

About 1660 the French in Quebec heard of the great village of the Illinois tribe at the site of the present Utica, and a few years later LaSalle, Hennepin, Tonti and others visited it. In 1680 a war party of eight hundred Onondagas marched from their village, now Syracuse, N. Y., and destroyed the Illinois town. While the history of your state begins about 1660, it is quite likely the French Courier de Bois entered the region long before that date.

But we are primarily interested in the prehistory of Illinois. Your mounds and monuments were referred to more than one hundred years ago in several publications. Up to the Civil War interest centered in Cahokia, at East St. Louis, and on Monks Mound in particular. The past nine years there has been increasing activity in thorough archaeological studies by two institutions, the University of Illinois and the University of Chicago. This does not mean that there were no men in the State of Illinois who did not appreciate the importance of its archaeology, or who had

not done good scientific work. Here I wish to pay tribute to two pioneers: Mr. George E. Sellars of your state experimented in flint chipping for many years and published a paper in the Smithsonian Institution report, 1885. Notwithstanding all the experimentation on the part of certain individuals in both Wisconsin and Ohio, I have seen no paper equal to that of Mr. Sellars of long ago. Dr. J. F. Snyder of Virginia, was a physician of high standing, who for more than forty years endeavored to arouse some interest on the part of Illinois institutions in their own antiquities. He had at his disposal very slender means, yet Snyder's papers, which were published by your Historical Society, Academy of Science and one or two other organizations, indicate a grasp of the essentials of Illinois archaeology far beyond his times. There is a tendency now to rather minimize or overlook the pioneers in American archaeology. I have always resented this, and I think it is very unfair to the men who labored under great disadvantages. They are entitled to their full meed of praise. Dr. Snyder and one or two others who did not lay claim to any scientific training, and yet were men of intelligence, always maintained that there was a difference between the artifacts found in southern Illinois, those of Cahokia, and along the Illinois River itself. They did not use the word *culture*. Snyder's explorations were accurately done, as is evinced in his papers.

Many years ago a movement was inaugurated to save the Cahokia Mounds, and particularly the dominant central figure, Monks Mound. The first effort failed. Then Dr. David Kinley, President of the University of Illinois, became interested in the subject, and thanks to his recommendations the Trustees appropriated money for a number of field seasons, with the result that a great deal of technical exploration was put into effect in the Cahokia region. Following that, a survey was made of the Illinois Valley from Peoria down as far as Kampsville. The report on this work up to December, 1927, has been published as a bulletin of the University of Illinois. A second report will be issued shortly.

A few years ago Dr. Fay-Cooper Cole, of the University of Chicago, began intensive work in central and northern Illinois, obtaining important results. It is now proposed that both the universities coöperate with reference to their field plans, and that the remains of the entire state be carefully located and mapped, and that a general scheme of coöperation as to archaeological studies be entered upon.

Because of rather extensive field operations, we are able to indicate that our facts tend toward certain conclusions. Yet at present we cannot solve all our problems. Flanking the Ohio River, southern Illinois, is an extension of the stone grave culture of the Tennessee-Cumberland regions. There is no question about this. Also near Cairo are the great flint quarries from which came most of those remarkable spades and hoes of brown chert so common in southern Illinois, southern Indiana, and eastern Missouri. In the southern part of your state have been found engraved shells and pottery forms characteristic of Missouri and Arkansas tumuli. The culture is distinctly southern, as stated, but yet rather different from Cahokia.

Proceeding northward we come to the great Cahokia group opposite East St. Louis. Go back fifty years. That was before a wonderful plain, the American Bottoms, became what Kipling would call "man-handled." Today it is wrecked, so far as beauty is concerned; gone are many of the evidences of prehistoric occupation. It is right and proper, and not unfair to anyone, for me to state plainly and bluntly that the people of southern Illinois made a tremendous mistake when they confined their state park to one-hundred and forty-three acres. True, they have preserved Monks and a few other tumuli. The old surveys, as well as our own survey, urged at Springfield, East St. Louis, and elsewhere, the preservation of the entire tract as a great asset to both the state and the country at large. Instead of that the politicians had their own way, with the result that today the state park is flanked by all kinds of buildings, concessions, race tracks, amusement pavilions, and the real spirit of Cahokia—if one may use the term—is gone forever. This should be qualified with the statement that it would be possible to restore the place to its original interest and beauty, but that would involve enormous expense in buying out the concessionaires.

Four seasons work at Cahokia enables one to make the positive statement that it is the farthest northward push of a distinctly Southern culture, and yet that cultural status is different, as I have said, from what I term the Tennessee-Cumberland, or Etowah, developments.

The Cahokians must have made use of one of these larger mounds as a mortuary for their distinguished dead. Up to the present time this burial place has not been discovered, yet all archaeologists believe it exists. It is necessary to locate it, because

there we will have for our study the art of the people. Obviously, one can not study art unless one possesses art objects.

The immensity of Cahokia dominates. The village site extends for six miles—from east of Monks Mound through East St. Louis to the mouth of Cahokia Creek. There is no village of that extent north of central Mexico.

We now proceed to the Illinois River valley, where we find two more cultures, and north of that, along the shore of Lake Michigan, in the Chicago section, is a typical St. Lawrence Basin culture, making five for the State of Illinois.

In the Illinois Valley, between Joliet and Kampsville, lived a very populous tribe. Inspection of the artifacts in stone and the ceramic art at Dr. Don Dickson's famous site and those found by Mr. George Langford at Joliet, together with the results of our own survey, leads one to the inevitable conclusion that these people were of that Illinois tribe whose last and large village was found by LaSalle and Hennepin, as stated. The Illinois reached from the historic period back into unknown prehistoric times. Within this culture and surrounded by it is a small and more compact tribe of totally different cultural status. I refer to the log-tomb people concerning which so much has been said in the newspapers.

The discoveries were made by ignorant men, and although they were carefully questioned by me personally, their accounts did not agree. Mr. Taylor, in charge of our work, spent more than two months in the Liverpool district watching the tunnel operations conducted by Mr. Ernest Dickson and Mr. Ogden, owner of a large mound. We were refused permission to explore mounds in the region; neither could we obtain consent to trench the Ogden mound, the spirit of commercialism being widespread in that part of the valley.

Details are too lengthy to be presented in this paper, but I shall be glad to explain further to those who are interested. It would appear that crude log tombs, or cists, were built. A layer of white sand was laid down, interments made on this, and the mound erected over all. The objects accompanying these burials are almost Hopewell in character—copper hatchets, human maxillaries cut into ornaments, bear tusks, imitation bear tusks in copper, pearl beads, monitor pipes, but no pottery. There were traces of fabrics here and there, which could have been saved by the use of preservatives.

There appears to be no relationship between the general Illinois culture and the log-tomb people, and the difference is quite as marked as between the Fort Ancient and Hopewell tribes of Ohio.

In his open-air museum at Lewistown, Dr. Don Dickson presents the most important exhibit *in situ* in this country. I make this statement intentionally. Here we have, in their original positions and setting, over two hundred remains, accompanied by mortuary offerings. The term "Fort Ancient" is rather unfortunate when applied to tribes of similar advancement throughout the Mississippi Valley, yet we have none other available. Put crudely, it may be said to represent neither a low culture (such as the rock shelters), nor yet a high culture (such as Etowah), but rather the average. The term middle-class, by which we designate the bulk of our white population, might with equal propriety be applied to the Fort Ancient culture. Thus, in the Illinois Valley, the greater body of middle-class Indians predominated.

Assuming nineteen type units in measuring cultural status of mound-building tribes, we would assign the Illinois Indians (Lewistown and Joliet sites) six units; the log-tomb people eight. By way of comparison one might state that Hopewell is assigned thirteen and Etowah eleven of these units. There are six units present at Hopewell that are absent at Etowah, and four found at Etowah that are absent at Hopewell. Another observer might make use of twenty or twenty-one type units in his scale of measurement. Mine is not final, but merely for my own convenience.

As I said before, while lower Illinois up to and including Cahokia is distinctly Southern, in the Illinois Valley Northern influence is the rule. True, you have certain forms in ceramic art found by both Mr. Langford and Dr. Dickson which parallel forms from Arkansas or Tennessee. Conversely, there are forms developed locally. It appears to me that sometimes we have unduly emphasized the presence of certain artifacts or utensils in one site which are duplicates of those found in a place hundreds of miles distant. We should base our observations upon the preponderance of the evidence. There is a tendency manifest in some of the recent papers in our technical journals to extend the borders of Caddoan, or Hopewell, or Iroquoian, or Siouan influence entirely too far. The finding of a few Hopewell types in Wisconsin does not necessarily prove that there was a well-established and extensive Hopewell center in that state, and this observation applies to other

sections. We must take into account the widespread aboriginal trade—how the specialized workmanship of certain familias or clans penerated to remote tribes. This is a very important subject, and has a direct bearing on our conclusions. I might mention a certain form of highly specialized flint spearhead found in southern and central Ohio. It is always of Flint Ridge pink and white, or bluish flint. These look as if they were made by workmen who followed an identical pattern. There are also the long ceremonial blades of the Etowah culture, all chipped in the same manner, and of practically unified forms. This observation applies to the engraved unio shells which portray the human figure crowned by antlers, and clad in feather robes. Without further detail, if the student observes carefully the character of the workmanship in these three types I have mentioned, he will see at once that they were produced in the same manner, or portray the same technique. A few of these clearly indicate ancient commerce. A majority of these or other designs indicate a culture.

To what origin shall we assign the truncated pyramids of the Cahokia group? There are none—or at least no clearly defined ones—in the entire Illinois Valley, a short distance to the north. Do they indicate a knowledge of Mexican civilization? We should not go that far. Yet how can we explain the presence of truncated pyramids? It is stated that there are two pyramids at Aztalan in Wisconsin, but they are not very large. Certainly, the truncated pyramid is distinctly Southern, and we have no preponderance of evidence in favor of Southern influence in Wisconsin. As our various institutions and individuals extend intensive field operations, I have become more and more convinced that while most of the tribes of the entire Mississippi Valley and the South were addicted to mound building, and thus in the broad sense followed a general custom, yet there were great differences in local cultural development. It seems to me that many of us have failed to recognize the importance of this factor in American archaeology. It applies to Illinois as well as to many other states. The great group at Cahokia was the result of occupation for a considerable period of time. Indians do not work hastily; certainly their development is rather slow.

In the report just recently published we have presented all available evidence to date concerning Cahokia. Time does not permit of repeating that here. One might say, however, that it was more than the northern outpost of a Southern tribe, it was a

veritable citadel of Indian strength. Imagine a village six miles in extent—we have proved that by our test pits. Was so populous a settlement inhabited at one time? I do not think so. The great village at Utica, according to French estimates, contained nearly ten thousand Indians, yet the field evidence—village site debris—at Utica is a mere fraction of that which appears on the surface at Cahokia. Moreover, the site at Utica has not been visited by thousands of tourists and collectors the past forty years as has Cahokia. With the exception of marine shells and galena, so far we have discovered no evidence at Cahokia of extensive aboriginal trade with distant Indians. The much more restricted log-tomb culture, on the contrary, presents exactly the reverse. Until some institution of your state thoroughly explores in the Liverpool district, we can not solve the log-tomb people problem.

Reverting to Cahokia, and of course basing my conclusions on field evidence to date, the people of that great site seem to have lived within themselves. They do not appear to have been much influenced by other tribes. This can not be said of most of the Illinois Valley.

Why were the elongated mounds at Cahokia placed so that their major axes were exactly east and west? Several of the early writers on Cahokia, observing the monuments before they had been changed through farming operations, were impressed by this fact. It was urged by some that these people had a crude knowledge of astronomy. Engineer Taylor, himself an amateur astronomer, has presented in our report three pages of astronomical observations and measurements. He does not believe in the theories of our predecessors; yet he finds it difficult to explain the placing of all the elongated mounds exactly east and west.

Our learned friends, the physical anthropologists, are in a position to shed much light on Illinois archaeology. There is accessible a great deal of skeletal material, particularly from the Illinois Valley and northern Illinois where Dr. Cole's assistants have done such good work. Very few crania from Cahokia are available, scarcely a dozen, yet we discovered over three hundred bodies, few of which could have been preserved even by the distinguished Dr. Hrdlicka himself. Physical anthropologists have an important duty to perform. Let them measure and tabulate the crania obtained in these log tombs, comparing them with those found by Dr. Don Dickson and Mr. Langford. This should be done soon, and we shall then be possessed of very important facts.

Paralleling this, there should be a study of the ceramic art of aboriginal people of every river valley in Illinois. Certainly, there are marked differences between the pottery of tribes along the Ohio River, Cahokia, Illinois Valley, and the lake district. One does not need to be an expert in ceramic studies to note variations between the pottery found in Cook County and that from Lewistown, scarcely one hundred and fifty miles away.

That the objects themselves, both from surface and burials, should be tabulated, goes without saying.

Most important is the mapping of all remains in the state before more of them are destroyed.

As to explorations or excavations, we know a great deal concerning the people of the Illinois Valley itself; also of southern Illinois. There should be, however, a concentrated effort through prominent citizens and organizations to secure several of the large and unexplored tumuli of the Liverpool district for thorough explorations. Undoubtedly, in these are more of the log tombs. The Illinois State Academy of Science has a duty to perform. It should use its great influence in coöperating with both universities named, also Northwestern University, the State Teachers' College, the State Historical Society, and all other organizations to arouse public opinion to this effect. In the Liverpool district are certain mounds as yet unexplored which properly excavated will solve that most interesting problem, the identity of the log-tomb people. The commercial spirit in that particular sector is widespread. It is a waste of time to argue with mound owners. We have tried that. Through careful preparation and coöperation of all the institutions named, as well as local societies, it is quite likely that you could persuade landowners to permit scientific examination of some of these tumuli. You will pardon the wearisome detail, but unless we take immediate steps, the pot hunters will cause further damage. I have advocated state legislation, but most of the gentlemen are against this, and say it would aggravate rather than cure the evil. I bow to the majority, of course, but personally I still believe drastic measures are necessary.

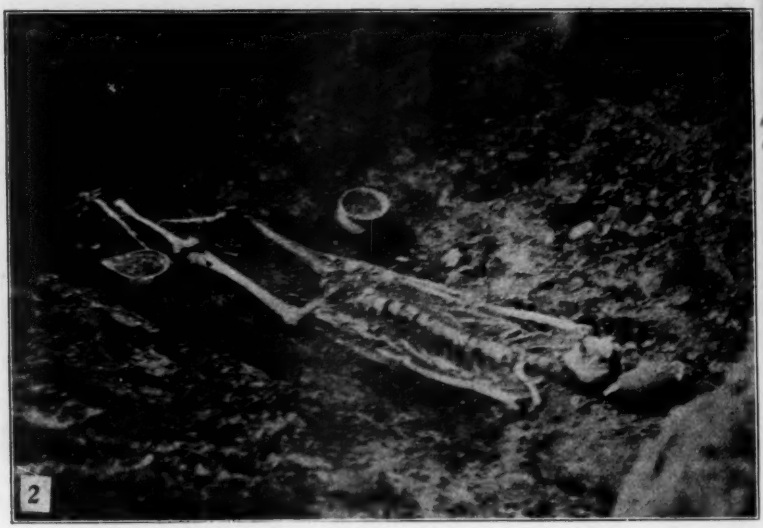
Finally, notwithstanding damage in certain sections of your great state, much remains. You possess a remarkable and interesting field. I trust that no one will consider me presumptuous or forward in offering the recommendations mentioned above. I believe that your major propositions are: first, the preservation of the remainder of the central Cahokia group; second, the thorough

and detailed exploration of certain strategic centers; third, the study of the crania and ceramic art; and, fourth, the mapping of all aboriginal remains.

(Above) East view of Monks Mound. *(Photograph by Gordon Severant.)*
(Below) The Powell Mound. *(Photograph by J. L. B. Taylor.)*

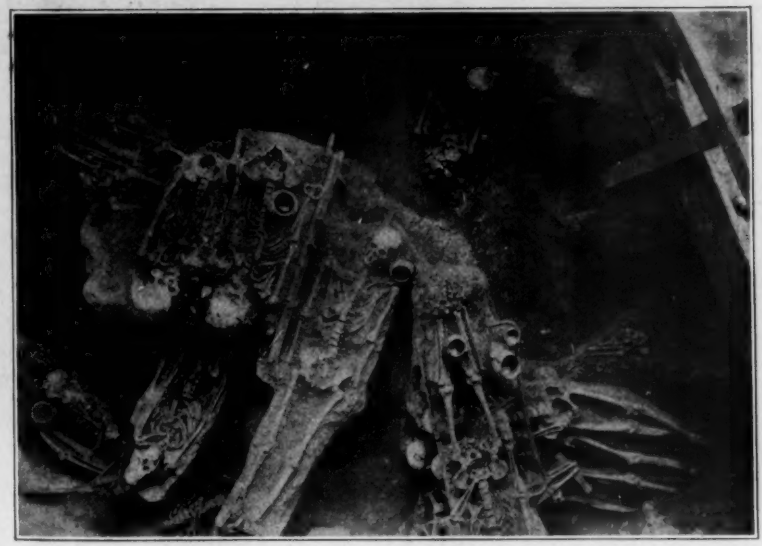
ACKNOWLEDGMENT

The plates used here are furnished through the courtesy of the University of Illinois Press.

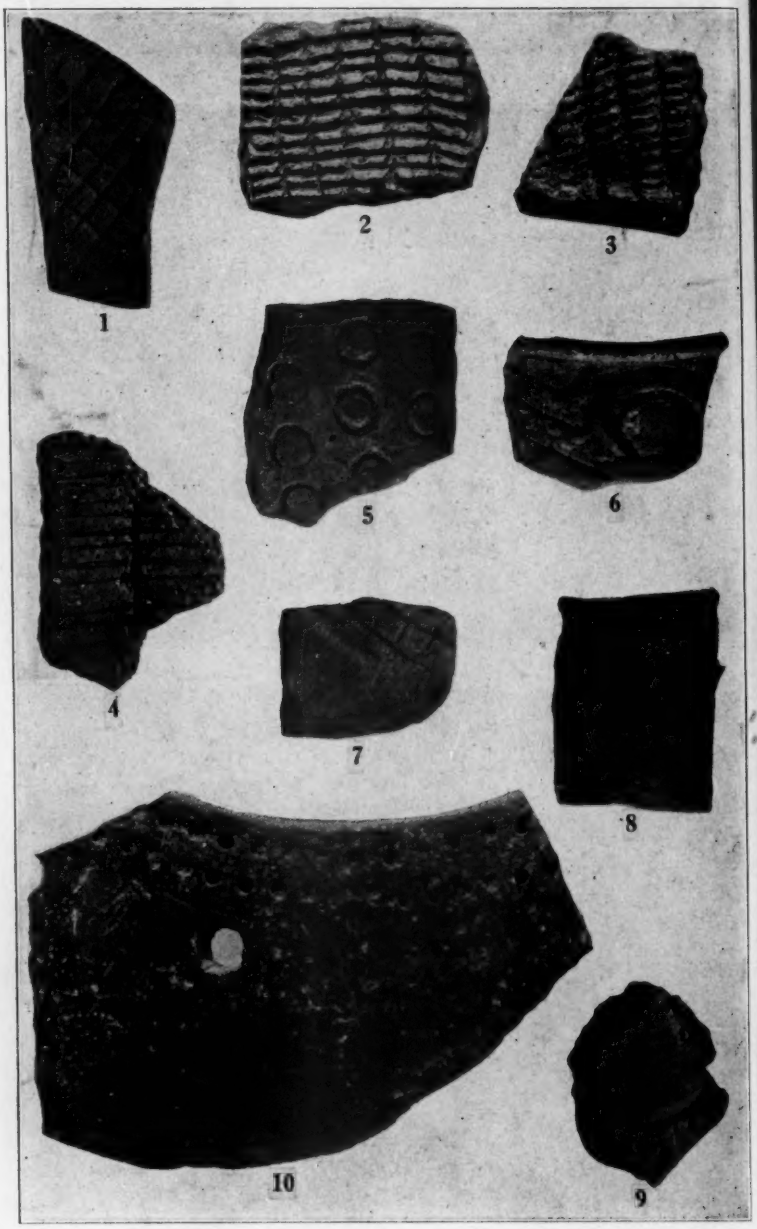


(Above) Skeleton No. 12, from Mound No. 20.

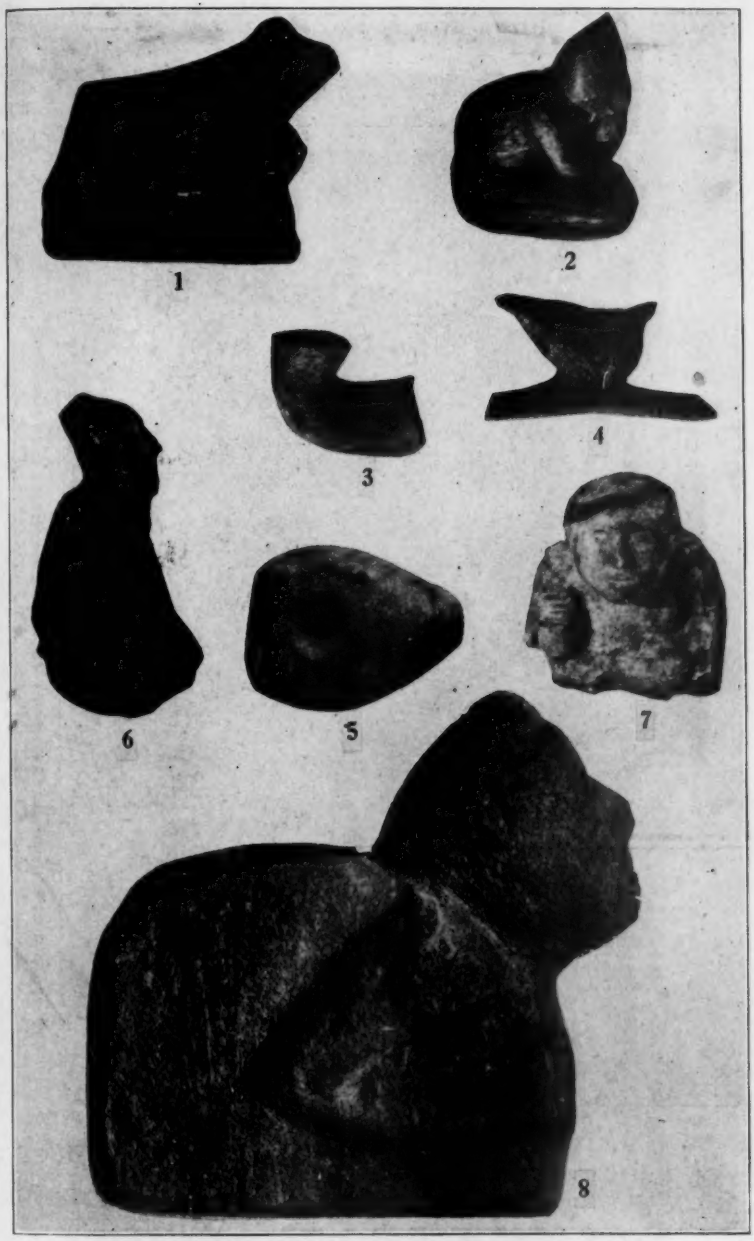
(Below) Skeleton No. 11, from Sawmill Mound.



Views of some skeletons and accompanying objects *in situ* in the mound owned by Dr. Don F. Dickson, Lewistown, Illinois.



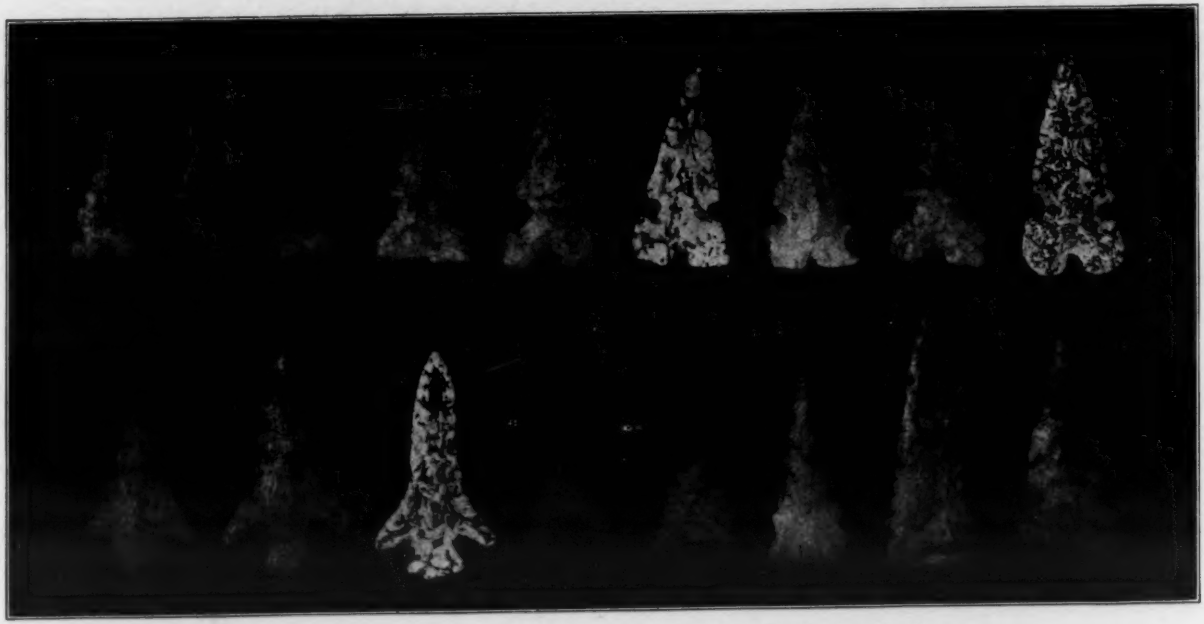
FIGS. 1-9. Fragments of pottery from the Wells-Tippetts Village Site.
FIG. 10. Peculiarly decorated pottery fragment, from the Ramey Village Site.



FIGS. 1-5. Five pipes, several of them effigies, from the Monticello Seminary collection. FIGS. 6, 7. Stone effigies, from the Monticello Seminary collection. FIG. 8. Large effigy pipe, from the W. J. Seever collection.

Objects from the log tombs near Liverpool: *(left)* bone daggers, 12 to 16 inches long; *(center)* pearl beads; *(right)* imitation bear teeth in copper, copper axes, and copper beads. From Dr. Don F. Dickson's Collection.

(right) imitation bear teeth in copper, copper axes, and copper beads. From Dr. Don F. Dickson's Collection.



The Cahokia type of arrowheads, from the collection of Dr. George Higgins.

Six bear tusks, two of which are split; three small copper hatchets; and a spearhead of agate-like flint—from the Neteler Mound.

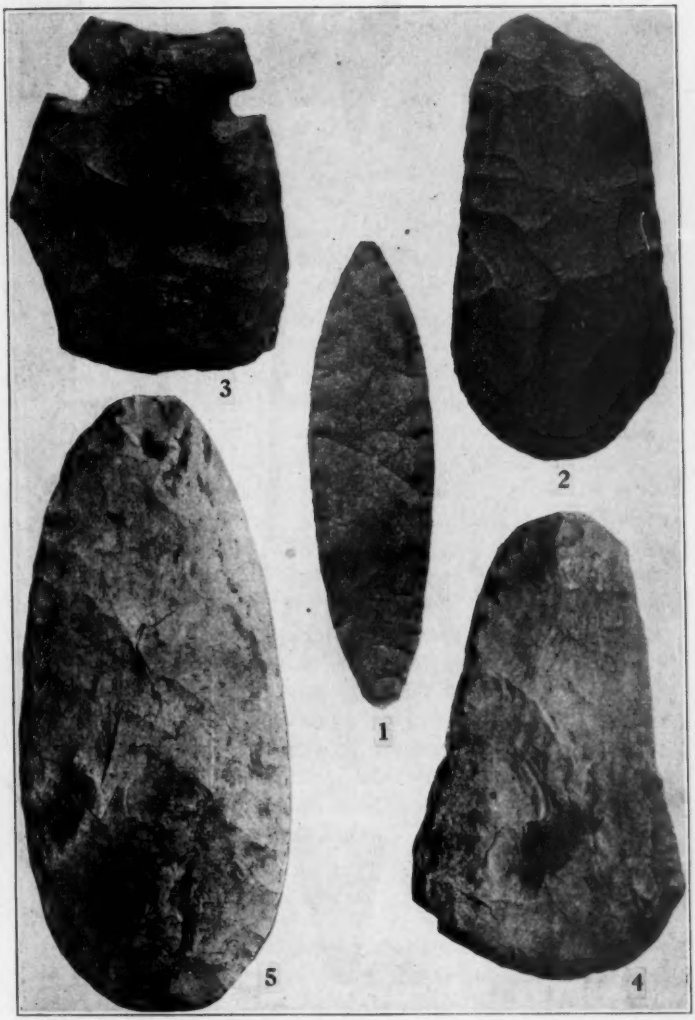


FIG. 1. Flint or chert knife of fine workmanship, from James Ramey Mound. FIGS. 2 and 4. Spades, of flint or chert, from field southwest of Monks Mound. FIG. 5. Spade from James Ramey Mound. (About 1/3 natural size.)

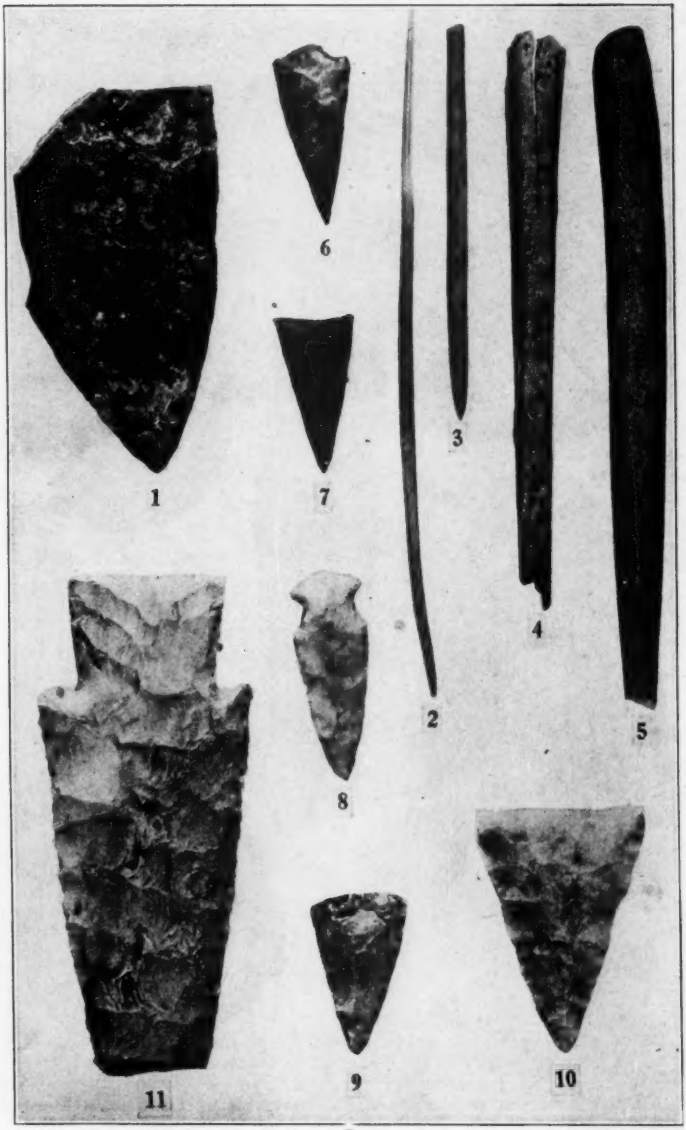


FIG. 1. Flint knife, broken. FIG. 2. Fine-pointed needle of bone. FIGS. 3-5. Bone awls. FIGS. 6-8. Flint arrow points. FIGS. 9, 10. Flint war arrow points. FIG. 11. Flint spear head. (FIGS. 2-5, ¾ natural size; 1, 6-11, about natural size. FIGS. 1, 6-8, and 11 from James Ramey Mound; FIGS. 3-5, 9, and 10 from Wells-Tippetts Village Site.)

THE USE OF ANIMAL LIFE BY THE MOUND-BUILDING INDIANS OF ILLINOIS*

FRANK COLLINS BAKER
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More than forty years ago a distinguished American zoologist, Dr. R. E. C. Stearns, wrote a very interesting paper on "Ethno-Conchology: A Study of Primitive Money," which was published in the Annual Report of the Smithsonian Institution (1887, part II, page 297). As a young man the speaker read this and other similar papers with great interest. As the years passed this interest grew. When the University of Illinois undertook the exploration of the Illinois mounds, particularly the Cahokia group, under the direction of Dr. W. K. Moorehead, one of the striking results was the discovery of the use of great quantities of mollusks, both of fresh-water and of marine origin, for a wide range of objects. With these mollusks were also the bones of deer and other animals, the whole indicating an extensive range in the use of animals in the domestic life of these primitive people.

One of the interesting features of the study of archeology is the attempt to reconstruct the everyday life of the people from the objects which they have left in their mounds or burial places. From a study of these we may picture the various uses to which the implements or artifacts were put: that this long sliver of bone was a needle for sewing clothing; that this shell with the inner whorls removed was a dipper; that this large clam shell with the perforation was a hoe for tilling the earth; and that this beautifully notched purple clam shell once adorned the ear, or nose, of some belle of the ancient community.

FOOD

Like many modern tribes of Indians and other more or less primitive people, it is probable that the women of the Mound Builders did a large part of the tilling of the fields and all of the domestic work, while the men were hunters and warriors. Hunting doubtless furnished a large part of the meat supply, which con-

* Contribution from the Museum of Natural History, University of Illinois, No. 54.

sisted of deer, raccoon, and possum among mammals, and such birds as the wild turkey, ducks, geese, and other large species. Fishing certainly was carried on, as bones of these denizens of the water have been found in the mounds. Even turtles and frogs formed a part of the diet.

River mussels doubtless formed a large part of the food supply of these Indians, for the shells of clams, either scattered or forming large masses of kitchen-midden, or refuse heaps, have been found in considerable numbers. A kitchen-midden of clam shells was found in one of the mounds in the Havana region which was of such a size as to almost confuse the zoologist as to their origin, the mass forming, apparently, a perfectly natural bed, like the Pleistocene formations so common in parts of the state.

Among the vertebrate animals used for food, the Virginia deer appears to hold first place, for the bones of this animal are found in all mounds. In the Cahokia group they occurred very abundantly, many of them being broken, apparently for the purpose of obtaining the marrow. That other mammals were esteemed is suggested by the presence of the remains of the opossum, the raccoon, and several squirrels. Even the beaver was used. Whether or not the great bison was used for food cannot be definitely stated from the bone relics, as only the teeth and the horns of very young animals have thus far been found.

Among birds, the American turkey was evidently a favorite, and long before our eagerly anticipated Thanksgiving Day was first set aside by proclamation, these early Indians may have celebrated, in the fall, a day of thanksgiving to the Great Spirit for a good crop and abundant game. With wild fowl plentiful and population relatively small, there could be a choice of bird food, and the presence of the bones of mallard and black ducks, blue-winged teal, several species of geese, and the trumpeter swan indicates the discriminative taste of these people. Of fish, the river carp and buffalo, as well as the fresh-water drum, were caught, and probably other large fish were also snared. Frogs, snapping turtle, and painted turtle indicate a liking for the same delicacies that more modern man now seeks.

It is probable that the large river snails, such as Campeloma and Anculosa, were used, as well, perhaps, as the larger fresh-water snails such as Lymnaea and Planorbis. Land snails are rare in the mounds, and there is no indication that they were used as food by the Illinois Indians, although many primitive people have used

these succulent mollusks, as attested by the finding of hundreds of specimens in the mounds of the Aurignacean people of the Old Stone Age in Algeria, by the expedition of the Logan Museum of Beloit College. Our larger land snails, such as the white-lipped snail *(Polygyra albolabris)*, would be fully as good for food as were the species contained in these mounds. Evidently the Mound Builders were not as far advanced in this respect as were these earlier people.

IMPLEMENTS AND ARTIFACTS

Not only were deer and other animals useful for furnishing the food supply, but their bones and hard parts supplied the raw material for many artifacts and implements of great value in the domestic economy. The Virginia deer was, perhaps, the most useful animal for this purpose, its bones being especially well adapted for the making of several essential tools. The heel bone (calcaneum) made an excellent awl or punch, the flat posterior portion forming a handle. The arm bone (ulna) also made an awl with a somewhat longer punching end, the bone below the upper end being ground to a long, fine, sharp point. Some awls or punches from the Chandler mound near Havana measured a foot in length, these being made from the metacarpal or metatarsal bones of the legs.

Even the lower jaw formed an excellent punch when the anterior end was rounded and pointed, the rear portion of the ramus forming a convenient handle. Several such tools were found in the James Ramey mound of the Cahokia group. One lower jaw, found in the Sawmill mound at Cahokia, was evidently used as a chisel or celt, the anterior end of the ramus being smoothed and squared. While the majority of the awls and punches were made of the leg bones, objects thought to be scrapers were made from portions of the pelvis, ribs, dorsal vertebrae, and shoulder blade. Very fine, long, and narrow bone objects are classed as needles and were made from the lower leg bones of the Virginia deer. One of the best of these objects, a slender piece six inches long and an eighth of an inch in diameter, was found with a skeleton in the group of mounds known as 19, 20, and 21. And the significant fact of this find is that the skeleton was that of a woman!

Mollusks of various kinds are the most common objects in the mounds of Illinois. The use of river mussels as food has already

been noted. Some of these mussels were made into spoons or scoops, often cut and ornamented. Broken shells were used as a flux with clay and formed a cementing medium in the making of pottery. Several specimens of a large clam were found that had been cut squarely across the shell, a hole being made in the center near the hinge line, and this is believed to have been a hoe.

Perhaps the strangest mollusks present in the mounds in fairly large numbers are the marine snails. These are not fossils deposited near the mounds by Pliocene or earlier seas, as has been thought by some people, but are all recent species, now living in the waters of Florida and the Gulf of Mexico, as well as the West Indies. The sea is now 500 miles away. A striking fact is that all species are of a tropical character, none inhabiting the colder shores of New England or New Jersey. All are distinctively those species living in the warm waters of Florida or the Gulf of Mexico.

How did the Mound Builders of Illinois obtain these shells in such quantities? It is possible that there might have been some transportation up and down the Mississippi and Illinois rivers and some barter in this way between the tribes of the Gulf coast and those of Illinois. But it appears more probable that they were obtained by barter from the tribes to the east or south, and that this bartering passed through many hands and many tribes before reaching the prairies of Illinois. That the barter may have been from Florida northwestward is suggested by the presence of similar species in the Hopewell mound of Ohio and in the mounds in Calhoun County, Illinois. That this trading was also of an extensive nature is attested by the abundance and diverse character of the species represented. Marine shells were much more highly prized than were the common mollusks found in the rivers and creeks of Illinois.

The uses made of these marine shells were various and their utility obvious in many cases. The great conch (Busycon), which attains a length of a foot, made an excellent dipper or scoop, or a drinking cup, when the inner whorls were removed and a portion of the body whorl cut away, the long canal affording a convenient handle. Such dippers occurred in the Cahokia group, in the Chandler and Neteler mounds of the Havana group, and in other places. The solid center axis of this conch also provided material for drills and punches. This species of conch *(Busycon perversus)* is to be regarded as one of the most valuable objects of raw material available to the Mound Builders.

Perhaps the most striking object of this class of animals is the large helmet shell, or Cassis, which occurs rather rarely in the Hopewell mound and in the mounds in Calhoun County, Illinois. This shell grows to about ten inches in length and has a diameter of about seven inches. When the inner whorls and a portion of the last whorl are removed, it makes a useful water jar or container. That this shell is rare and difficult to obtain by the Mound Builders, is shown by the fact that but two specimens occur in the Calhoun County collections and but one in the Hopewell collection of the Field Museum in Chicago. The presence of this Cassis in these two places suggests trading or barter by an overland route rather than by the Mississippi River.

PERSONAL ADORNMENT

Personal adornment was evidently considered as much of a virtue among the Mound Builders as it is among the swains and belles of today. Some of this was probably simply for the purpose of enhancing the personal charms of the wearer, but among the men, at least, it also undoubtedly indicated the standing of the individual in the tribe as regarded his personal bravery, either in conquering some wild animal or in victory in warfare. In the Neteler mound in the Havana group, great numbers of the canine teeth of the black bear were found in connection with burials. The teeth were either whole or split longitudinally, and all were pierced with one or more holes for suspension about the neck as a necklace. As many as fifty of these teeth were found in one grave, indicating that the owner, possibly a chief, had killed some twelve bears. As the killing was done with primitive weapons, arrows or spears, this feat is to be ranked as one worthy of note.

The strangest objects found in the Neteler mound were the cut and squared lower jaw of a human being and those of an Indian dog, both pierced with two holes, apparently for suspension about the neck. These were probably used as amulets or charms and are apparently rare in Indian mounds. Whole upper jaws with the palate were found in the Dickson mound near Lewistown, Fulton County.

Beads of various kind are common objects with all primitive people, and they were made in abundance and apparently commonly worn by the Illinois Mound Builders. Some of the large discs made from the marine conch may have been used as money

and strung for this purpose, but the beads for pure adornment were much smaller and were made from a variety of objects, all mollusks, however. The flat side of the marine conch, Busycon, was a favorite source of supply. Other marine shells were also used for this purpose, as the fasciolaria, the strombs, and the olives. The solid axis of the conch was much used, resulting in a thick, rounded, button-like object, pierced with one hole in the center.

Snails, both marine and fresh-water, were used abundantly and could easily be made by grinding one side of the body whorl until a hole was formed into the inner cavity. These shell beads were strung by passing a cord through the natural opening and the artificial hole. Several species of small marine snails were used in this manner, as the marginellas, periwinkles, and small conchs. The small river snails, however, appeared to be the favorite for this purpose, and thousands of the little Anculosa have been found in the mounds of the Cahokia group and in Calhoun County mounds. The larger Campeloma snails were also used, but not to so great an extent. The fresh-water mussels were often used as a pendant, many such being found which had been pierced with two holes, apparently for this purpose. Some of these shells occurred with burials apparently as a sort of bracelet or anklet on the legs above the ankles.

Beads made from barouque pearls of the fresh-water mussels occurred in great numbers in the Chandler and Neteler mounds in the Havana group. They were carefully bored and must have made striking ornaments when strung and hung about the neck of some dusky maiden. The boring of the holes in these small pearls must have been a slow task and required a high degree of skill on the part of the workman. These pearls did not occur in the Cahokia or Calhoun mound groups.

DOMESTIC ANIMALS

No domestic animals such as have been used by modern Indians have been found in the mounds. The nearest approach to such is the presence of the bones of Indian dogs somewhat resembling certain breeds now found in Alaska and in Greenland and eastern America. How the dog came to be among the Mound Builders of Illinois is not perfectly clear, but it may have arrived here by way of British America through barter with the intervening tribes. Dogs of various sizes are known from shell mounds in Maine which are pre-Columbian in age.

ART

The ethnologic scale of a people is largely indicated by their art—the objects which they have made by the use of thought—in other words, their culture. This is largely indicated by pottery, which is now considered one of the best indicators of the degree of culture among primitive people. But it may also be indicated by other objects, and among the Cahokia Mound Builders several such made of shells indicate a rather high degree of culture. One outline Indian head, made of the flat side of a pink heel-splitter mussel was found in the Sawmill mound. The outline is perfect, the nose characteristically Indian, the chin sharp and prominent. In the same mound a shell gorget of peculiar design was found, made from the same species of river mussel. The beautifully worked ear pendant found in the James Ramey mound, mentioned before, made from the purple river mussel called the spike, is another example of primitive art. In this even the bright purple color has been retained after a lapse of several hundred years. In one of the Calhoun County mounds there was found a small object which indicates a well-developed cultural taste. Made of the side of a marine conch shell, it is about two inches long, disc-like, one end having the head of a bird beautifully carved in profile.

That the makers of the mounds so abundant in Illinois were observant students of nature is strikingly shown by their use of natural objects as ornaments on the rims of their pottery. Such were found quite commonly in the Cahokia group and included clay heads of birds, suggesting the spoonbill duck, some of the game birds, as prairie chicken, perhaps the passenger pigeon, and a mammal, possibly intended for a wild cat. Whole jars or vases known as effigy pottery also occur in some of the mounds. An effigy jar about four inches high was found in the Rose mound near Bluff City, Schuyler County, the upper part representing the head of an owl, possibly a screech owl, the eyes and nose being graphically shown. Another owl-like jar was found near Pittsburg Lake, Cahokia region, which represented the top of an owl's head, only the ears being shown. Frogs and other animals are known to have been used as effigies in other places in Illinois, particularly on pipes of both clay and stone.

SYSTEMATIC LIST OF SPECIES

I have appended a systematic list of the different species of animal life used by the Mound Builders, as shown by the material in the museum of Natural History of the University of Illinois, gathered for the most part by the parties under the direction of Dr. W. K. Moorehead during the past five years. A single collection of large size was made in Calhoun County many years ago and exhibited at the World's Columbian Exposition in Chicago in 1893. This list indicates strikingly the wide use made by these primitive people of the natural resources about them, which helped to make life easier and to enable them, also, to give expression to cultural aspirations, which apparently were strongly developing.

For assistance in this list, the writer is indebted to the following colleagues:

Bird bones,—Dr. Alexander Wetmore, Assistant Secretary, Smithsonian Institution, and Director, U. S. National Museum.

Mammal bones,—Mr. Gerrit S. Miller, Curator, Division of Mammals, U. S. National Museum.

Fish and reptile bones,—Dr. Alvin R. Cahn, Department of Zoology, University of Illinois.

Bird, fish, and mammal bones,—Dr. L. A. Adams, Department of Zoology, University of Illinois.

A summary of the animal life used by the Mound Builders shows the following numbers of species among the different groups:

	All Mounds Studied	Cahokia Group	Illinois River Group
Mollusca:			
Marine species	12	10	3
Fresh water mussels..	23	16	12
Fresh water snails....	4	4	2
Total Mollusca ...	39	30	17
Vertebrates:			
Pisces	3	3	1
Amphibia	1	1	0
Reptilia	2	2	0
Aves	8	8	0
Mammalia	12	7	9
Total Vertebrates .	26	21	10
Grand Total ..	65	51	27

The predominance of the Cahokia group over those on the Illinois River is noteworthy, especially in the use of marine mollusks and of birds.

Systematic records of the use of animal life by prehistoric Indians are rare. Among those noted is one by F. B. Loomis and D. B. Young (Amer. Jour. Science, iv, XXXIV, pp. 17-42, 1912) which lists the relics of animal life found in the shell heaps of Maine, including 39 species, of which 18 are mammals, 5 birds, 7 fish, 1 turtle, 1 frog, and 7 mollusks. Sea urchins are mentioned as forming food rarely. The following species mentioned also occur in the western mounds in Illinois: deer, black bear, raccoon, beaver, and domestic dog. Among the birds, only the brant is common to both areas. As in the Illinois material, a large part of the animal life was used as food, although deer and other bones were used for making harpoons, fish hooks, and needles. Dr. W. K. Moorehead states that bone implements and artifacts were common in the Hopewell mound group, Ross County, Ohio. Bear teeth, split and perforated, were abundant. Carvings of high merit made on bone were numerous. No mention is made, however, of the use of any animals as food. The use of fossils, particularly the large tooth of the huge fossil shark from South Carolina, the *Carcharodon megalodon*, is noteworthy. None such have thus far been found in the Illinois mounds, as far as is known to the writer (*see* The Hopewell Mound Group of Ohio, Field Museum of Nat. Hist., Anthro. Ser., Vol. VI, No. 5, 1922, by Warren K. Moorehead).

PHYLUM MOLLUSCA

MARINE GASTROPODS

Busycon perversa (Linn.) Conch Shell. Left-handed.

The most abundant marine shell in the mounds. Found in all mounds examined, including the Cahokia Group, near East St. Louis, and those in Mason, Schuyler, Calhoun, and other counties bordering the Illinois River. Uses: dipper or cup made by removing inner whorls; awls or punches from center axis; beads from heavy center axis; rounded discs from thinner outer or body whorl; small specimens smoothed, polished and grooved for suspension as a pendant about neck with necklace, possibly of beads; whole spire (flat) of shell forming rounded disc, use unknown. In Calhoun Co., a fine bird-head effigy was carved from the side of a shell of this species.

Busycon carica (Gmelin). Conch Shell. Right-handed.

Not as abundant as *perversa*. Used as dipper. Found only at Cahokia.

Busycon pyrum (Dillwyn). Pyriform Conch Shell. Right-handed.

Rare. Found only at Cahokia. Used as pendant, a hole being drilled in the lower part of the canal.

Fasciolaria gigantea Kiener. Giant Spindle Shell.

Cahokia group only. Portion of center axis, use not apparent.

Fasciolaria distans Lamarck.

Cahokia group only. Several whole shells, use not indicated.

Strombus pugilis alatus Gmelin. Stromb or Conch Shell.

Cahokia group only. Two specimens, one whole; one piece of spire whorls, apparent use as pendant or ear ornament.

Cassis madagascariensis Lamarck (= *Cassis cameo* Stimpson). Cameo Shell, Helmet Shell.

Calhoun County. Two fine specimens of this large cameo shell were found in the Calhoun County mounds many years ago. These specimens have the inner whorls removed, thus making the shell an excellent receptacle for holding water, grain, or any small material. Fragments of this shell occur in village debris near the Don Dickson mound, Lewiston group.

Murex pomum Gmelin. Rock Shell or Purple Shell.

One specimen was found with burial in the Rose mound, Bluff City, Schuyler County. Its use is not apparent.

Oliva litterata Lamarck. Olive Shell.

Cahokia group only. One specimen with top of spire removed, possibly used as pendant.

Littorina irrorata Say. Periwinkle.

Cahokia group only. One whole shell. Use not indicated.

Marginella apicina Menke. Marginella Snail.

Cahokia group only. Many shells occur with a hole ground on one side, this, with the natural aperture, forming two holes making it possible to string the shell in the form of beads.

Rangia cuneata Gray. Marine Clam Shell.

Cahokia group only. Three specimens, one left valve, two right valves. Use not indicated.

AQUATIC PELECYPODS

Mussel shells probably obtained mainly from the Mississippi River and the Illinois River.

Fusconaia ebena (Lea). Niggerhead Mussel.
Cahokia group, rare. Use not indicated.

Amblema costata Raf. Three-ridge.
Common. Cahokia group only. One specimen used as hoe.

Amblema rariplicata (Lamarck). Blue-point.
Common in mounds in Mason and Schuyler counties. Used for food.

Amblema peruviana (Lamarck). Blue-point.
Rare in Cahokia group. Use not indicated. Possibly for food.

Megalonaias gigantea (Barnes). Washboard.
Cahokia group only. Several specimens apparently used as hoes.

Quadrula quadrula Raf. Maple-leaf.
Cahokia group only. Use not indicated.

Quadrula cylindrica (Say). Rabbit's Foot.
Cahokia group only. Rare. Use not indicated.

Quadrula pustulosa (Lea). Pimple-back.
Havana mounds. Not common. Use not indicated, possibly for food.

Tritogonia verrucosa (Raf.) Buckhorn.
Havana group. Rare. Use not indicated.

Cyclonaias tuberculata (Raf.) Purple Pimple-back.
Cahokia group, made into shell hoe; Havana group, possibly for food.

Plethobasus cyphyus (Raf.) Bullhead.
Havana group. Rare. Use not indicated. Possibly food.

Pleurobema coccineum solida (Lea). Small Niggerhead.
Havana group. Common. Probably used as food.

Elliptio dilatatus (Raf.) Spike or Lady-finger.

Cahokia group; Mounds on Illinois River. This is the commonest river mussel in the mounds and occurs abundantly in all groups. It was evidently largely used as food, occurring in great numbers in kitchen-middens; it was also made into ornaments. A fine specimen of this shell occurred in the James Ramey mound, Cahokia group, which had been made into an ear ornament. It retained in a remarkable degree the delicate purple color of the species. In the Rose mound, Schuyler County, a specimen had been worked for some ornamental purpose, but had evidently not been finished.

Elliptio crassidens (Lamarck). Elephant's Ear.

Havana group. Probably used as food.

Truncilla truncata Raf. Deer-toe.

Cahokia group only. Use not indicated.

Plagiola lineolata (Raf.) Butterfly.

Havana group. One specimen. Possibly used as food.

Proptera alata megaptera Raf. Pink Heel-splitter.

Cahokia group. An effigy representing an Indian's head was found in the Sawmill mound and an ornamented shell gorget of peculiar design was found in mounds 19, 20, 21. A left valve of this species was found in the Rose mound, Bluff City, Schuyler County. It was unworked. This mussel, although very abundant in both the Illinois and Mississippi rivers, appears to have been little used by the Mound Builders.

Ligumia recta latissima (Raf.) Black Sand Shell.

Cahokia group only. Rare. Possibly used as food.

Lampsilis anodontoides (Lea). Yellow Sand Shell.

Cahokia group only. Rare and use not indicated.

Lampsilis fallaciosa (Smith) Simpson. Slough Sand Shell.

Cahokia group, rare. Havana group, rare. Use not indicated.

Lampsilis siliquoidea (Barnes). Fat Mucket.

Cahokia group only. Not common and use not indicated.

Lampsilis ventricosa occidens (Lea). Pocket-book Mussel.

Cahokia group, rare. Havana group, rare. Probably used as food.

Lampsilis ovata (Say). Pocket-book Mussel.

Cahokia group. Several large valves of a mussel appear referable to this species rather than to *ventricosa,* to which they were previously referred. The shell is thinner than *ventricosa* and the heavy posterior ridge is more like *ovata* than *ventricosa.* These have been worked into scoops or spoons. In the Rose mound, Bluff City, Schuyler County, a number of mussels occur which are referable to this species. One specimen is large, about four inches long, and was evidently used as a scoop. It was found with a burial, in mound no. 13. In mound no. 12, associated with burial no. 1, there were eighteen shells which had been cut to small size (1½ to 2 inches long) and a hole drilled at each end. These were found around the leg of the skeleton above the ankle. The shell from which they were cut is probably the *Lampsilis ovata,* as two large shells from the Rose mound are of this species. The same species occurs with burials in the Dickson mound. It is interesting to note that this species is not found in either the Illinois or Mississippi River, but occurs in the Ohio River. The Indians must have obtained the shells by barter, as in the case of the shells found in the Cahokia group.

USE OF PEARLS

In the Kamp mound near Kampsville, Calhoun County, and also in the Neteler mound near Havana, Mason County, there were found quantities of barouque pearls of the river mussels, in association with burials. These had been made into beads by boring a hole through the center of the pearl. Pearls were also found in the Dickson mound, and consisted of barouque, hinge, and some free pearls. None were observed in other mounds and none occurred in the Cahokia group.

FRESH WATER SNAILS

Anculosa praerosa (Say). Round River Snail.

This is one of the most abundant snails in the mounds, used in all cases for the purpose of making beads by grinding a hole in the side of the shell, which, with the natural aperture, provides two holes and forming a bead which may be strung. Very common in the Cahokia group; in Calhoun County; and in the Hagans Mound, Browning, Schuyler Co. It was not observed elsewhere.

Campeloma ponderosum (Say). Heavy River Snail.

Several specimens of this large river snail occurred with Calhoun County material. They were bored to form pendants on a necklace. Two specimens were found in the James Ramey mound, Cahokia group, use not indicated.

Campeloma integrum (Say). River Snail.

Three specimens of a Campeloma occur with material from the Wells Village Site which are referable to this species rather than to *subsolidum* (= *crassulum*) as before recorded. They were used as beads.

Pleurocera acuta tracta (Anthony). Slender River Snail.

A few specimens of this snail occurred in the James Ramey mound, Cahokia group. Use not indicated.

In the Cahokia group there were many specimens of mollusks found which were evidently introduced with the building material, and hence cannot be considered as of archeological value. Their presence, however, should be recorded, and they are listed below:

Stagnicola palustris elodes (Say)
Stagnicola reflexa (Say)
Helisoma trivolvis (Say)
Planorbula armigera (Say)
Physella gyrina hildrethiana (Lea)
Viviparus contectoides W. G. Binney
Anodonta grandis Say
Helicodiscus parallelus (Say)

PHYLUM CHORDATA

CLASS PISCES

Ictiobus bubalus (Raf.) and *Carpiodes carpio* (Raf.).

Opercular bones of a species of buffalo fish were found in the James Ramey mound village site. Smaller opercular bones believed to be of the river carp were also found. These suckers were evidently used as food.

Aplodinotus grunniens Rafinesque.

The pavement-like lower pharyngeal teeth of the fresh-water drum were found in the Tippetts village site, Cahokia group; and in mound no. 6, Havana group, Mason County.

Unidentified fish vertebrae also occurred in the James Ramey mound, and the operculae of an unidentified fish in the Sawmill mound.

CLASS AMPHIBIA

Rana species.

The lower jaw of a small species of frog was found in the James Ramey mound.

CLASS REPTILIA

Chelydra serpentina (Linn.)

The hooked lower jaw of a snapping turtle occurred in debris from the James Ramey village site. A portion of the plate of the plastron was found in the Edwards mound.

Chrysemys cinerea (Bonn.)

Several fragments of the plastron of the western painted turtle were found in the James Ramey village site.

CLASS AVES

Anas platyrhynchos Linn.

Humerus of mallard duck from base of mound west of Merrill house, at depth of 3½ feet. Broken bones which may be of either *Anas platyrhynchos* or *Anas rubripes* (the black duck) were found on the James Ramey mound. Two humeri and a tibio-tarsus are represented.

Querquedula discors (Linn.)

Humerus and tibio-tarsus of the blue-winged teal were found in the James Ramey mound.

Chen caerulescens (Linn.)
Chen hyperborea (Pall.)

Metacarpal, humerus, radius, and ulna bones of geese occurred in the base of a mound west of the Merrill house at a depth of 3½ feet; the Saw Mill mound; the James Ramey mound. Dr. Wetmore says that perhaps both the blue and the lesser snow goose may be represented, and as the bones vary somewhat in size it is quite possible that this may be so.

Branta canadensis (Linn.)

Humerus, metacarpal, radius, and tibio-tarsus bones of the Canada goose occurred in the James Ramey mound.

Cygnus buccinator Richardson.

A single bone, the lower end of the metatarsus, of the trumpeter swan, was found in the James Ramey mound.

Gallinula galeata (Licht.)

A lower part of a tibio-tarsus of the Florida gallinule was found in the James Ramey mound.

Anatidae, species unknown.

Several bones of ducks occurred in the James Ramey mound which are not determinable.

Meleagris gallopavo silvestris (Vieill.)

Metacarpal, tibio-tarsus, and tarso-metatarsus bones occur in the James Ramey mound. Some of the leg and wing bones have been broken, evidently by the Indians during consumption of the turkey as food.

CLASS MAMMALIA

Didelphia virginiana Kerr.

Four rami of lower jaws of the opossum with the teeth intact were found near Abbott mound no. 2, near Naples, Scott Co., in a fireplace 3½ feet beneath the surface of the ground.

Odocoileus virginianus (Bodd.)

The bones of the Virginia deer were found in all mounds and in many village sites. They were most abundant in the Cahokia group. Many of the leg bones had been broken to obtain the marrow. The remains of this animal have also been found in the Havana group, Mason Co., near Bluff City, Schuyler Co., near Naples, Scott Co., and several places in Calhoun Co. This deer was the most used animal for the manufacture of bone implements. The leg bones, especially the metarcarpals or metatarsals, were used in making punches, awls, scrapers, etc. The calcaneum was a favorite for making short punches because of the excellent handle formed by the end of the bone. Longer awls were made from the ulna. Dorsal vertebrae and portions of the pelvis made good scrapers. The ribs were made into scrapers, and in one example, a small celt. Lower jaws were fashioned into punches and chisels or celts. A shoulder blade (scapula) made a scraper. Spike horns of young deer made good awls or punches. Some of the leg or arm bones (humerus or femur) were curiously incised and carved on one end, the use not being clear. In short, there was scarcely any bone of this animal that was not used for some purpose. This animal may be considered the most valuable natural asset of the Mound Builders, furnishing both food and material for useful implements.

Cervus canadensis (Erxleben).

A specimen of the lower end of the metacarpal bone of the elk, or Wapiti, curiously incised, was found in the James Ramey mound.

Bison bison (Linn.)

Several molar teeth of the American bison, or buffalo, were found in the fireplace near the Abbott mound number 2, near Naples, Scott Co. Relics of the bison are rare in the mounds. What are taken to be horns of very young bison were found in mound number 6 of the Havana group.

Sciurus carolinensis Gmelin.

A humerus of the southern gray squirrel was found in the James Ramey mound.

Sciurus niger rufiventer (Geoffroy).

A humerus and a femur of what is probably the western fox squirrel occurred with other bones in the fireplace near the Abbott mound number 2.

Castor canadensis Kuhl.

A portion of the right lower jaw of a beaver was found in the fireplace near Abbott mound number 2.

Canis cf. familiaris Linn. Variety.

Skull of adult animal and left ramus of lower jaw of puppy found in the James Ramey and the Sawmill mounds of the Cahokia group. Skull and lower portion of radius found in fireplace near Abbott mound number 2. A cut lower jaw was found with burials in the Neteler mound of the Havana group.

Comparison of these relics of dog-like animals indicates clearly that they do not belong to the coyote or prairie wolf, the frontal bones being much higher and the contour of the top of the head with a greater angle over the supraorbital region. The carnassial tooth is different and like that of the domestic dog, and there appears to be no question but that these animals were varieties of *Canis familiaris,* or common dog. A skull submitted to Mr. Miller was identified as that of a dog.

The presence of these apparently undoubted bones of the dog raises the question as to how they came into the possession of the Mound Builder Indians. Most of the mounds are believed to have been occupied in pre-Columbian times before the white man traded European material with Indians, and it is not likely that the dogs could have been acquired in this manner.

In the paper previously quoted, by Loomis and Young, reference is made to the finding of several types of dog in the shell heaps or kitchen midden of Maine (p. 25). These are believed to antedate the coming of the white man and to be upwards of 300-500 years old. The Illinois dogs appear to be like the type D of Loomis and Young, having a dental length of about 80 mm., and the head is rather short and chunky. Mention is made of similar dog remains from burials in Cross Co., Arkansas. As these authors state, there should be a systematic study made of the dogs found in the Indian mounds and shell heaps.

It is possible that the dogs might have been obtained by barter from more northern regions where the Eskimo tribes possessed

Skull of domestic dog from Sawmill Mound, Cahokia Group. (About 2/3 natural size.)

dogs, and the remains in the mounds may represent variations of these ancestors. References to the presence of dog remains in the mounds are rare, apparently, although no systematic attempt has been made to consult all of the literature.* Moorehead states that they did not occur in the Hopewell group in Ohio.

Taxidea taxus (Schreber).

A complete skeleton of the badger was found in the Rose mound number 13, near Bluff City, Schuyler County. It was buried

* Dr. Carl E. Guthe, of the University of Michigan, informs me that the dog is found in the early cultures of the Southwest and that it is believed to have been domesticated in the Old World and brought over with the aborigines during their migrations. This may be equally true for the mound-building Indians of the Mississippi Valley and would account for the presence of the bones of this animal in the mounds. Since the present paper was written, a rather complete skeleton of a dog has been found in material from the Hagan mound, Schuyler County, associated with a human burial.

on its right side with the head bent back over the left side, at a depth of two feet. This is apparently an actual burial and not a case of cave-in of a burrow. Human burials occurred in this mound at depths of two and three feet, but the significance of the badger burial is not apparent. Perhaps it served some ceremonial purpose.

Ursus americanus Pallas.

The left ramus of a lower jaw of the black bear was found in the fireplace near the Abbott mound number 2. A pierced canine tooth of a young animal was found in the Sawmill mound, Cahokia group. In the Neteler mound, near Havana, Mason County, great quantities of the canine teeth of the adult animal were found in connection with human skeletons, usually about the neck, where they had been worn as a necklace. Many of the teeth had been split longitudinally, and all were bored with either one or two holes. Bear teeth also occurred in the Dickson mound.

Procyon lotor (Linn.)

Disconnected rami of the lower jaws of the raccoon occurred in the James Ramey mound of the Cahokia group, and in the fireplace near the Abbott mound number two of the Illinois River group.

Homo sapiens (Linn.)

The use of human bones is rare in the mounds of Illinois. The most noteworthy and surprising use of these was a lower jaw found in the Neteler mound near Havana. This was evidently the jaw of one individual, the right and left ramus treated separately. Both are squared to be used as pendants, the right ramus with two holes near the ascending portion at the rear, and the left ramus pierced near the front end. With this jaw occurred the lower jaw of a domestic dog similarly squared and bored for suspension. In the Dickson mound, near Lewistown, Fulton County, a whole upper jaw with the palate was found. Just what significance these human bones may have in the culture of the Mound Builders is not perfectly clear, though they were probably in the nature of amulets or charms. In the group of three mounds, known as 19, 20, 21, in the Cahokia group, there occurred a portion of a human tibia which had been worked into some sort of tool or ornament.

ACKNOWLEDGMENT

The following plates were supplied by the University of Illinois Press.

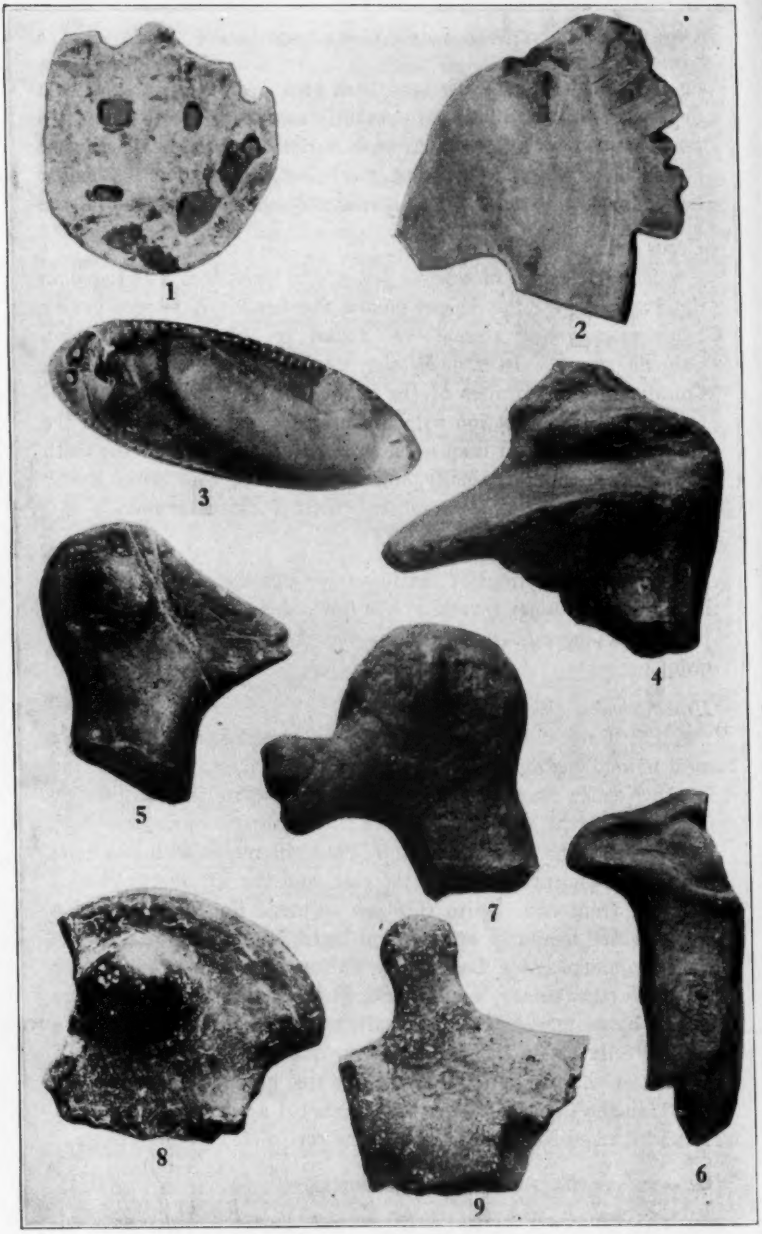
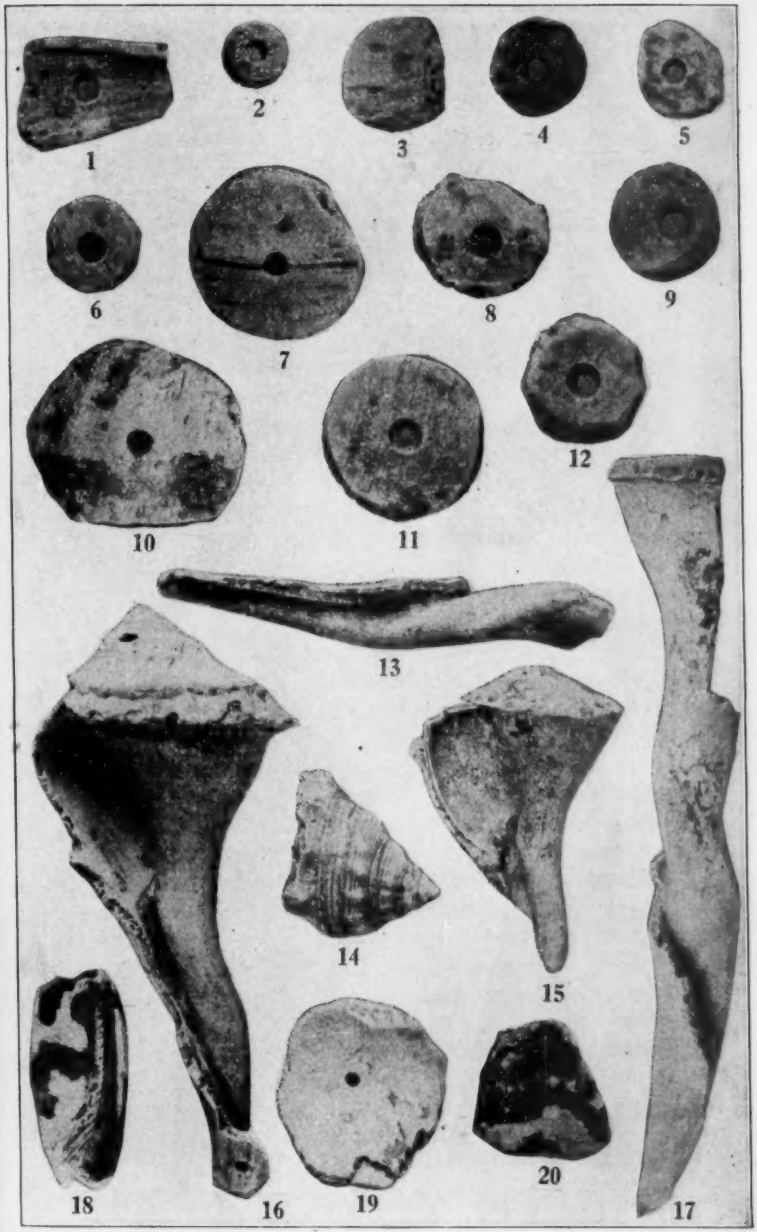


FIG. 1. Shell gorget. FIG. 2. Shell effigy made from shell of fresh water mussel. FIG. 3. Nose or ear ornament made from shell of fresh water mussel *(Elliptio dilatatus)*. FIG. 4. Clay bird's-head effigy. FIGS. 5, 6. Clay bird's-head effigies. FIG. 7. Clay mammal-head effigy. FIG. 8. Portion of clay pot or ornament. FIG. 9. Ornament on rim of pot. (¾ natural size.)



FIGS. 2, 4, 9, 12. Shell beads made from marine conch *(Busycon)*. FIGS. 5, 6. Shell beads made from fresh water mussels (A330). FIGS. 1, 11. Shell ornaments from marine *Busycon*. FIGS. 7, 8, 10, 20. Shell ornaments made from fresh water mussels. FIGS. 13, 15, 17. Shells and central axis of marine conch, *Busycon perversa*. FIG. 16. Marine conch, *Busycon carica*. FIG. 19. Ornament made of side of *Busycon* shell. FIG. 14. Marine shell, *Strombus Pugilis alatus*. FIG. 18. Marine olive shell, *Oliva literata*. All from James Ramey Mound, between 8 and 23 feet below surface. (FIGS. 1 to 12, about natural size; 13 to 20, about 3/5 natural size.)

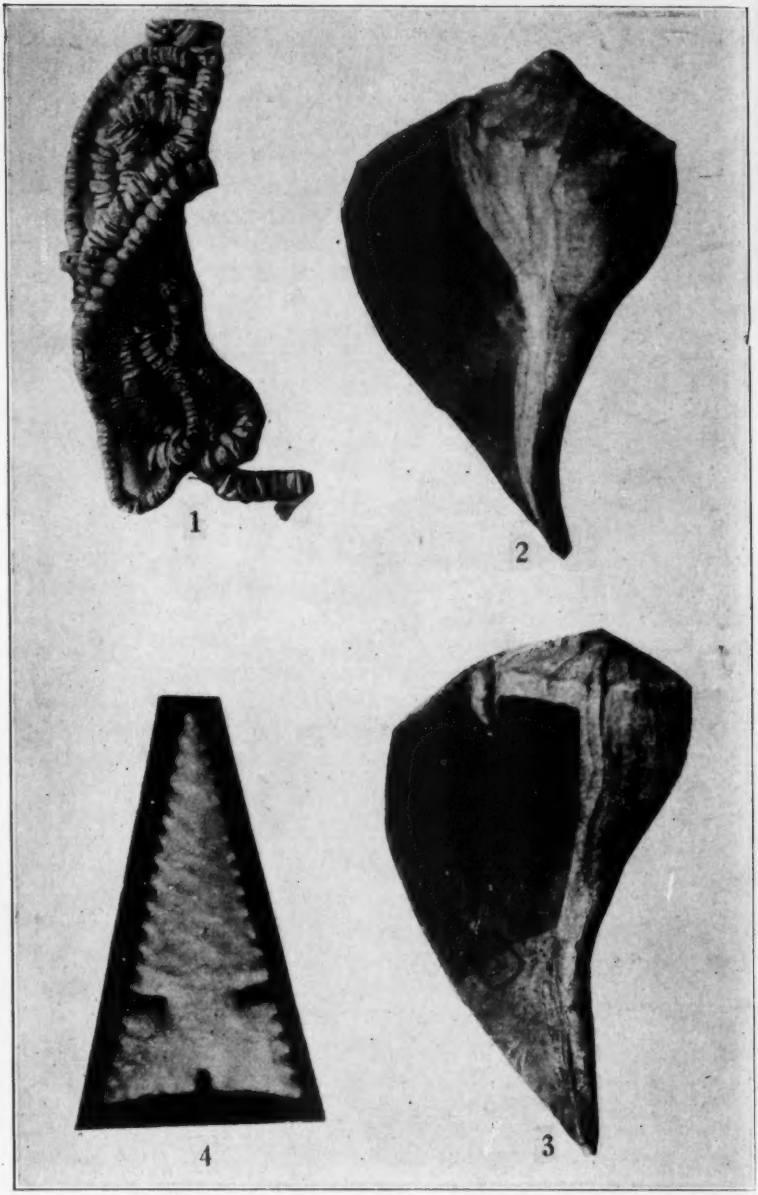


FIG. 1. String of shell beads cut from busycon conch. FIG. 2. Marine conch shell, *Busycon carica*. FIG. 3. Marine conch shell, *Busycon perversa*. From the Monticello Seminary collection. (¼ natural size.) FIG. 4. Arrowhead of quartz, unusual workmanship, found on the surface of Monks Mound. (Natural size.)

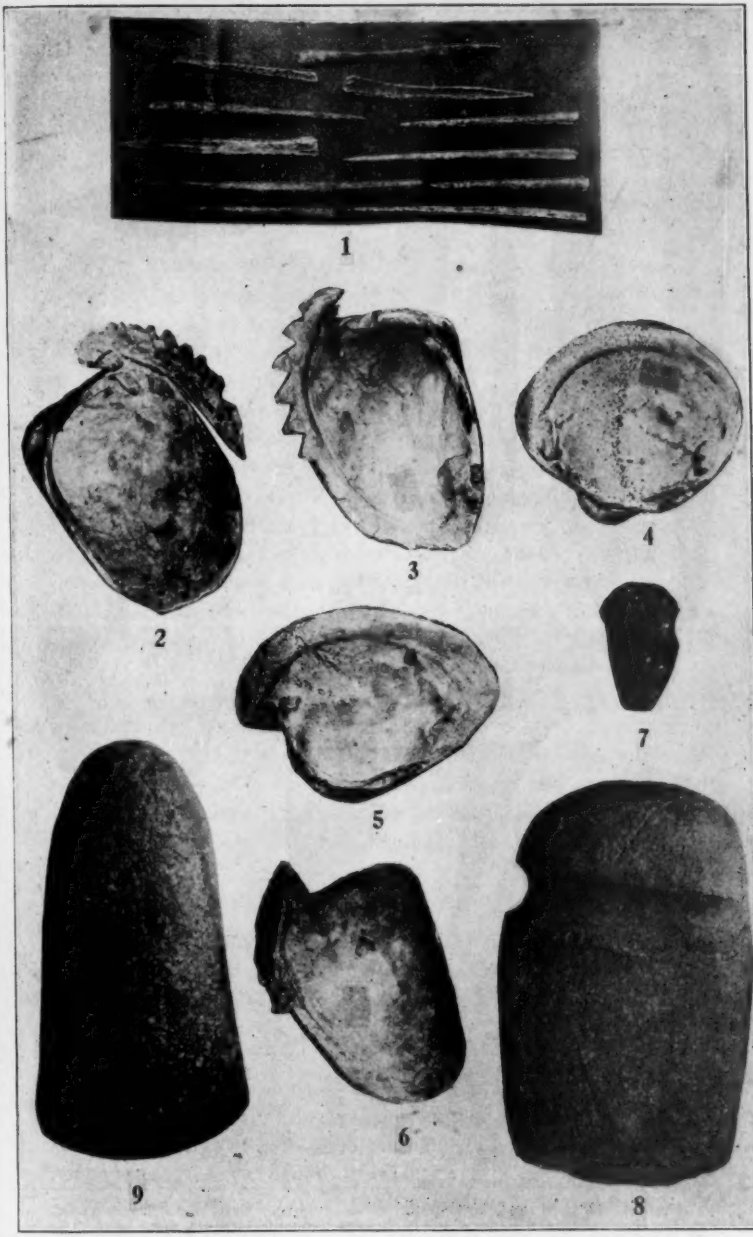
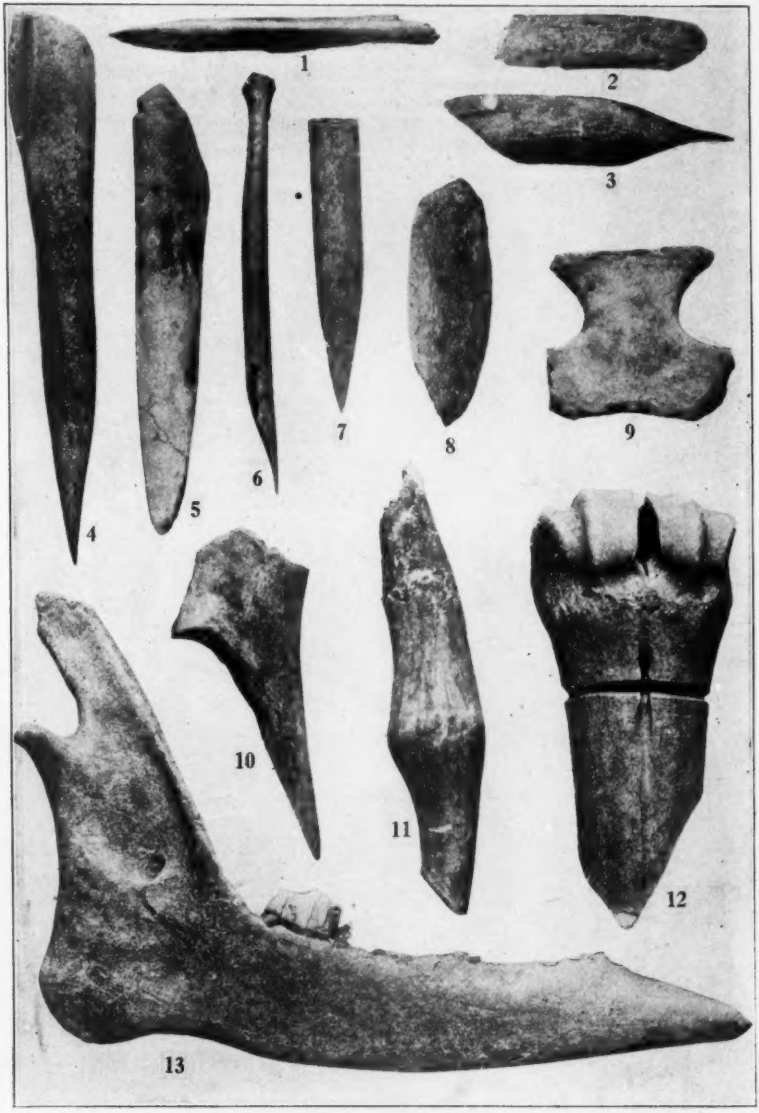


FIG. 1. Bone awls and needles. FIGS. 2-6. Mussel shells (*Lampsilis ventricosa*). From the W. J. Seever collection. (¼ natural size.) FIG. 7. Hematite axe. FIG. 8. Grooved axe. From the Monticello Seminary collection. FIG. 9. Celt of porphyritic rock, from the Wells-Tippetts Village Site. (1/3 natural size.)



FIGS. 1, 2. Awl and celt made of deer bone. FIGS. 3-7. Bone awls. FIG. 8. Bone knife. FIG. 9. Part of breast bone of Virginia deer. FIG. 10. Awl made from heel of deer. FIG. 11. Pathologic leg bone of deer. FIG. 12. Foot bone of Wapiti with deeply incised lines. FIG. 13. Lower jaw of Virginia deer used as a chisel or gouge. (About 2/3 natural size.)

GEOLOGY AND THE INDIAN MOUNDS

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The scientific excavation of Indian mounds, together with the reading of the record which they hold, is a special field that requires of the archeologist broad training, much experience, and special technique. These requirements have become more exacting as the methods have become more refined, and the student who now anticipates a career in Indian mound archeology pursues a college and graduate curriculum of broader scope than ever before. There are those subjects which bear on human anatomy, pathology, psychology, racial origins, primitive customs and practices, religious ideas and rites, primitive occupations, methods of construction and transportation, Indian history and traditions, primitive art, identification of earth materials found in the mounds, determination of their sources, the structure and age of the mounds, and a technique of excavating, recording, and collecting that will bring results for an ultimate interpretation of the Indian record.

In the course of the excavation of the Cahokia and Illinois River groups of mounds by W. K. Moorehead and J. L. B. Taylor under the auspices of the University of Illinois, the writer has coöperated in a study of the geological aspects, and as a result has become very much interested in the application of geologic science to the study of Indian mounds.

SETTING AFFORDED BY HISTORICAL GEOLOGY

First of all, there is the historical setting of the human race in geological history. During the geological ages, which have spanned hundreds of millions of years, the life of the earth has developed progressively from primitive to highly advanced types, at least partly if not largely in response to the changing conditions of climate, physiography, oceanography, food supplies, life competition, and certain special geologic conditions. Rocks older than the Cambrian have revealed thus far no life higher than the invertebrates; the Cambrian strata recently have yielded what appears to be a part of a fish; the Ordivician rocks, definitely fish; the Mississippian, amphibians; the Pennsylvanian, reptiles; the

Jurassic, birds and lower types of mammals; the Eocene, generalized mammals; and the late Pliocene or early Pleistocene, man.

Europe and Asia have furnished many evidences of early man, and where these have been found in glacial outwash gravels or in caves where they have been preserved by travertine deposits, they are a subject of common conversation among the local residents. The fact that America has not as yet yielded undisputed evidence of Pleistocene man should make the glacial geologists examine very critically the upper surface of buried interglacial soils for such evidence. In many places in Illinois, Iowa, and adjacent states, these old soils very clearly show places where subsequent invading ice-sheets left the very top of the old soil undisturbed, and places where the late Pleistocene loess covered old soil, only to be uncovered by erosional and artificial excavations.

Furthermore, workmen operating gravel pits in the outwash valley trains of the glaciers should watch for evidences of man, either fragments of his skeleton or artifacts, and report them to the glacial geologists of the State or Federal surveys or University faculties while they are still in place, before the stratigraphic evidence of their natural entombment is destroyed. The geological profession of this country, the writer feels, has been neglectful in interesting the laymen and school children in earth history, and as a consequence there is little foundation as yet for geologists to build on in trying to interest the uneducated. The less the attention paid to conserving the evidences of early man in America, the more hopeless the case of trying to uncover his record.

THE PROBLEM OF DETERMINING THE AGE OF THE INDIAN MOUNDS

All of the mounds in Illinois which contain no European culture and which occur on valley floors that are degraded below the surface of the Wisconsin valley trains are obviously older than the European human invasion of North America and younger than the last glacial epoch. The lack or small amount of erosion of the gulley type on their slopes, together with the depth of the virgin soil profile that is found on the mounds, shows that while the mounds may be several hundred years old, they are geologically very recent, perhaps not a thousand years old. Indeed, the shallow character of the soil and weathering zone which passes over the mounds confirms this conclusion.

But it should not be taken for granted that all of the mounds are so recent. A comparison should be made of the soil profiles which pass over the mounds, the depth to which they have been developed and the amount of secondary mineral substances which have been formed. In making this comparison, consideration and evaluation of several factors are necessary: angle of slope, texture and porosity of the material, the character of the native vegetation—whether prairie grass or forest, the size and form of the summit area, the height of the mound, and the composition of the original earth materials. The mounds which show the deeper weathering, other things being equal, are the older, and their content of artifacts should show a corresponding difference from the others, though not necessarily a more primitive culture.

The Cahokia mounds, so far as examined, and the Ogden and Dixon mounds, near Sepo, all show soil profiles in their infancy of development. Weathering has scarcely proceeded to any perceptible depth, charcoal and calcareous material are found close to the surface, and there is almost no separation into the various horizons so characteristic of the older drift materials. In contrast, the soil profiles which were found to pass under one of the Cahokia mounds—the only one opened to sufficient depth—and the Ogden mounds, show a very much more intensive and deeper development, with variation in color due to varying degrees of oxidation, and with secondary pellets of iron oxide.

The Dickson mound on the bluff of the Illinois River is on a deposit of loess which has been but little weathered, and so the mound is geologically very young, probably less than a thousand years.

STRUCTURE OF THE MOUNDS

There are great structural differences in the various mounds, showing that they were built differently. The Sam Chucallo mound of the Cahokia group was first a low mound in which burials were made, and then later built and rounded over to a height of about ten feet—a very simple type. The James Ramey mound of this same group showed several stages of construction: there were at least two very definite streaks of dirt running through the mound at different levels. The dirt streaks were clearly not true soils, simply surfaces which had been used for a time before the mound was built higher. In other words, the mound had a tabular summit at two stages of its construction, and finally it was rounded over into a cone.

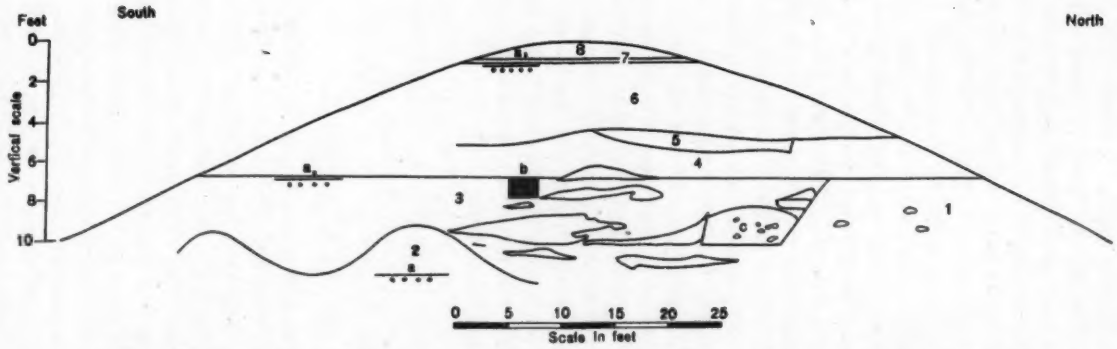

Fig. 1. Diagrammatic sketch of the west face of the James Ramey Mound. The letters *a* represent the sites of bonfires on old surfaces, marked by two well-defined dirt-streak horizons. For further details see "The Cahokia Mounds." University of Illinois Bulletin, Vol. 26, No. 4, pp. 125-127, 1929.

The Ogden mound which has the residence on its summit shows a still greater complexity of design and construction. Tunneling has disclosed log tombs, later covered over with earth until its original summit reached a height several feet higher than the present mound. White man has since reduced it and extended the mound laterally with the material obtained, making the summit wider. Near the base of the mound, about 2¼ feet above the old soil, the Indians spread a thin layer of sand before building the remainder of the structure, which is too complex to be adequately described in this paper. In places the silty clay is stratiform, that is, in crude thin layers, as if the material had been carried in baskets and spread out by hand. In other places the material is lumpy and of different colors of yellow, rusty-brown, drab, and

FIG. 2. The Ogden Mound at Sepo, Illinois. (Photograph by Applegate.)

light-gray, as if it had been intimately mixed before it was placed. In still other places the material is loose and lumpy as if it had fallen into a small room.

The Dickson mound on the bluff was primarily a burial mound, with but little excavation to start with, and then additions of loessial material were made from time to time as other bodies were superimposed. The burial groups of this mound, including children as well as adults, suggest that this was built during a pestilence.

Mounds which show, by their structure, different stages of building deserve special attention in the collecting of artifacts, particularly if there is any suggestion of a changing culture between the stages.

KINDS AND SOURCES OF MATERIALS USED

The identification of the kinds of materials used, and their sources, is very important. In the main they are soil and subsoil materials obtained nearby, but in special instances a small quantity of material may be found in the mounds which had other sources, as for example, the fireclays of the Coal Measures or the

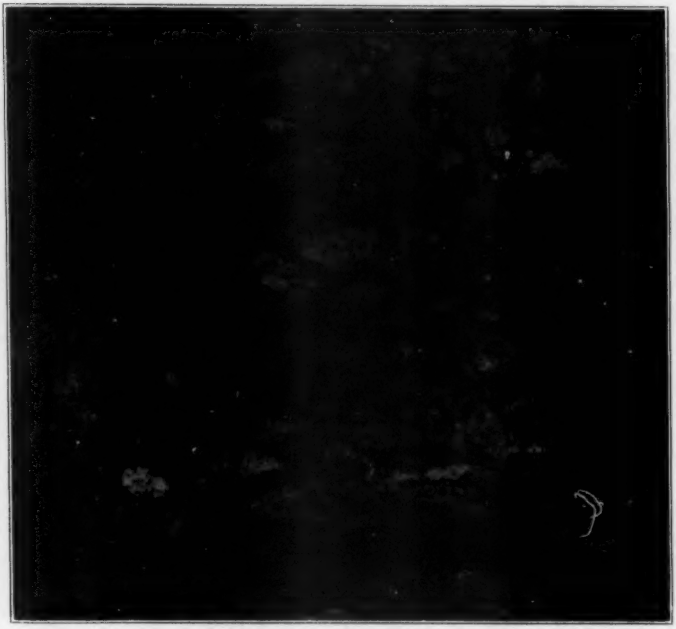

FIG. 3. View of wall in a tunnel through the Ogden Mound, showing the mottled effect of the intimately mixed clays of different colors. (Photograph by Applegate.)

bluff loess of the region. Fragments of travertine are found scattered through some mounds, suggesting that they were taken from some prized spring. In other cases special kinds of rock materials other than native copper may be found which, if the source can be located, may carry special significance.

RELATIONSHIP TO PRESENT OR ABANDONED STREAM CHANNELS

The location of mounds on water courses has an obvious significance. Some mounds are considerably removed from present channels but are on old deserted channels, suggesting that there has been a change in river courses since the mounds were built. Other mounds have a topographic position high up on bluffs, or considerably away from valleys. The purposes for which these were built might well have varied from those along the channels, and likewise their cultural contents.

The foregoing discloses that there are some aspects of Indian mounds of interest to the geologist, to the interpretation of which geologic science may contribute. The historical geologist in particular is anxious that the history of the earth and its inhabitants be completely deciphered and carried down to the present, and the development of the inorganic world and the organic world properly placed in time perspective. The preservation of the record of early man, whether glacial or recent, is bound to be of increasing value as the mass of people catch this perspective.

METHODS OF DETERMINING PREHISTORIC CHRONOLOGY

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Northwestern University, Evanston.

"Chronology is the essential framework of prehistory in the same sense that it is of history. The difference is one of degree rather than of kind: history requires absolute chronology, prehistory only relative chronology."

—MacCurdy, "Human Origins."

In a specialized discussion such as this symposium on the Archaeology of Illinois, it is perhaps well to pause for a moment to consider the larger setting in which the contributions are implicitly imbedded. It is for this reason I feel that, although in no sense a specialist in the field covered by the morning's topic, I may still contribute a background against which the light thrown by the other papers may be all the brighter. That chronology is a basic aspect of archaeological research has been amply demonstrated by the preceding paper. For the question "When?" in prehistoric research is fully as important as the questions "What?" or "How?" and the immensity of the time-depth envisaged since the coming of man to this earth makes the first question a pregnant one. Dr. MacCurdy's comparison, quoted at the beginning of this paper, clearly states the case; let us consider the significance of an understanding of chronology for archaeological understanding; what, indeed, do we know of prehistoric sequences?

As the curtain of history rises slowly over the world, it is no unset stage indicative of rude beginnings that greets our eyes. Rather the sumptuousness and sophistication of the arrangements, and the number and variety of the actors, presuppose long periods of preparation, and indicate that what we are witnessing is but the latter phases of a drama which has long been in progress behind the dropped barrier. Yet it is not easy for us to understand that knowledge of the preparatory stages of what we witness may have as great a significance for our comprehension of the drama of history as close attention to the unwinding of that drama itself has given. It is only recently that the prehistoric development of man has claimed the attention of scholars, perhaps because the events

in which they live, and those of which they have exact knowledge, have so intrigued them that students did not wish to take the time to investigate the humbler beginnings.

Let us first inquire into the nature of the events which characterised prehistoric society. Were they fundamentally different from those which occur at the present, or which have occurred since the beginning of prehistoric times? As far as we know, the answer is a negative one, the essential difference being perhaps in the size and complexity of society then and now. It is the nature of our information concerning them that is different from that of cultures existing since the historic period. Our knowledge of prehistoric cultures is much more generalised, and concerns the fundamentals of social life to a much greater degree than any historian would find necessary to deal with. There is an entire lack of that specificness of reference which the historian seeks as a matter of course.

What are the major difficulties which the prehistorian must face in making his record? Why must he be as vague as he is, and why must prehistory be so largely inferential? These impediments are four in number. First, there is the utter lack of written record, which restricts us to never more than hints concerning the intangibles of human activity. Then, such remains as are vouchsafed us are not found in their complete form, and what we must deal with are, therefore, fragments of the material cultures the people possessed. In the third place, we do not by any means have complete distributions, and this is most important. And finally, and most serious of all, is the absence of a time-table; of a chronological sequence universally applicable to which the data may be unfailingly referred.

Recognition of this lack came almost as soon as the study of prehistory itself, and as early as 1836 Thomsen set up his classification of prehistoric time as the ages of Stone, Bronze, and Iron. Obviously, such a rough chronology would not suffice, and many refinements were later introduced. There are three factors which must be considered in the making of a prehistoric time-series, all of which have been utilized. The geological formation of the land and the evidences of climatic change, the palaeontological character of the flora and fauna, and finally, the nature of the archaeological remains themselves, all contribute toward dating a given find. What is the relative importance of these three, and how are they used by the working archaeologists?

Geology is perhaps the science most closely related to that with which we are dealing—how closely, we have seen in the preceding discussion. Where the passage of the year marks a unit of time for the historian, that of a geological period may be said to be that of his colleague who is concerned with prehistoric dating. Investigating the early history of mankind, we find that man's existence does not begin until the very end of the Tertiary, or, better still, the beginning of the Quarternary. During this epoch, there was a series of four glaciations. During each of these four periods, the increasing coldness of the earth sent huge glaciers creeping from the north, covering all of northern Europe and America, and down the sides of the mountain ranges. These took great deposits of stone and earth with them. As the climate in each inter-glacial period became warmer, the glaciers in receding dropped their burdens, leaving clear indications which mark the points where the farthest reach of the glaciers was achieved. During the warm periods, also, large surface deposits of loess were laid down by the wind or water.

It is at this point, as Dr. Baker's contribution demonstrated, that the palaeontologist steps forward. During the warm epochs certain flora and fauna are to be found which are vastly different from the life that inhabited the continent during the cold ones. We therefore can utilize the animal types that were associated with given forms of early man in assisting us to date a given prehistoric phenomenon which we may find in association with them, and thus further establish our time-table. Indeed, in post-glacial periods in northern Europe, these indications are the best we have, marking small climatic changes with great fidelity. When enough of this type of association has been achieved, the typological forms of artifacts may themselves be standardized, and, if used with the greatest caution, may serve further to refine the table of time-duration achieved through the use of these other types of data.

Given a prehistoric site, then, how does the archaeologist go about dating his finds? Obviously, he must first attempt to ascertain its undisturbed character, and the geological period represented by the matrix in which it is found. If associated with his find there are the bones of animals other than man, the position is further strengthened by ascertaining what animals were contemporaneous with the makers of the artifacts, and whether they are those which the geological aspect of the site would cause to be expected in the given stratum. Finally, the nature of the artifacts themselves must be established, first by working out their

typology, and then by comparing them with the work of other prehistoric men who may be thought to have lived during the same period. If all these tests are satisfactory, the date of the find may be regarded as having been established. This is for finds made in the open. However, many remains have been found in caves, where geological data are not available. In these, careful stratification shows cultural changes through succeeding levels of debris to be excavated, and comparison with palaeontological specimens and other artifacts serve to establish the periods which are represented. It goes without saying that every remnant of the forgotten culture must be described as to the depth and location in the site as carefully as possible, and a wealth of technique to this end has been worked out and is the rule in archaeological research.

As a result of comparison, of untold effort in digging, and of much discussion, a consensus of opinion on the part of the scholars has thus worked out a reasonably satisfactory chronology for Europe. It must be remembered that the periods are relative in length; I give no numbers of years, as this is a matter of great doubt and much dispute. The rule of thumb is that the later the culture, the less time it occupied,—which merely says that one principle evolved by the archaeologists is that the more man has to build on, the faster he will build. At the beginning, so shadowed that its very existence is disputed, is the Eolithic period. Perhaps this came before the beginning of the Quarternary,—at best it is to be admitted in our chronology on sufferance. The Pre-Chellean and the Chèllean epochs, however, which follow it, are undoubted, and these, with the Archeulean, make up the Lower Palaeolithic. Then comes the Mousterian, the time of *Homo neanderthalensis*, occupying the cold Middle Palaeolithic. The Upper Palaeolithic, wherein Man as we know him appears, comprises the Aurignacian, the Solutrean, and the Magdalenian cultures. Palaeolithic times are followed by the short and unsatisfactory Mesolithic, with the widely-spread and almost contemporaneous periods of the Azilian, Tardenoisian, and Maglemosian. After these, the Neolithic, where in the south we almost touch on historic times, but in the north are still in the dimness of later prehistory. The Neolithic—not only to be distinguished as the age of polished stone, as used to be believed, but the period when such important innovations as the use of domesticated animals, pottery, the plow, and others, came into being—is followed at varying periods by the Bronze, and this

by the Iron age. Always these new later impulses seem to work their way northward from the Mediterranean; while Egypt had its Iron age in full flower, Scandinavia was still in the Neolithic. But the sequences hold for any given locality, and the chronological periods described give us a time-progression on which we can base satisfactory conclusions as to the development of European man up to the dawn of history.

Thus in Europe prehistoric finds may be dated with certain sureness. What of the rest of the world? In Africa, for example, we are outside the glaciated belt. It is impossible to obtain closely correlated types of geological evidence which will date the archaeological finds as surely as is the case to the north. Certain sequences corresponding to those obtained in southern Europe have been established for northern Africa, notably thru the work of Dr. Collie and his colleagues of Beloit College, but where we must evaluate finds from the Congo, from Rhodesia, or from South Africa, we are at a loss. That two sets of flint chipping seem alike in their style, is no assurance that they belong to the same epoch, although the temptation to date them in this fashion becomes almost overwhelming in the absence of other controls. Associated faunal remains are not satisfactory, for we cannot be sure that the animals which lived in Europe at a given time had their counterparts in other continents contemporaneously with them. The same holds true for Asia. Nelson's finds in the Gobi desert look as thought they are pre-Neolithic. But, as is the case in the Saharah, they are found on the surface where the action of the wind has exposed them, and as a result there is the greatest reluctance to express a given date for them.

This is not greatly different from the situation in which the American prehistorians find themselves, except that here the time element involved is perhaps not as long as in Europe. When did Man come to America? It is a question which has been much debated, but never satisfactorily answered. That man came during the Pleistocene,—that is, before the Neolithic period—has been vigorously denied, nor have the proponents been able to find certain answer to those who make their denials. It is true that recent finds in the Southwest, composed of finely-chipped arrows associated with the skeletons of an extinct variety of bison, have given new impetus to the controversy, but the finds merely make the point urged in the last paragraph, of the difficulties involved in utilizing only associated faunal evidence. For the Southwest is outside the glaciated region, and, since there are no time-tables of

a geological nature sufficiently precise, the palaeontologist can merely assure the pre-historian that the variety of buffalo found has been extinct a long time. But how long he cannot say with any certainty!

Such being the case, the American archaeologists have been compelled to start with the known and cautiously work their way back. In the Southwest, in Mexico, in Central America, and in Peru, the main centers of archaeological interest aside from the Mississippi and Ohio valleys, the aboriginal inhabitants had contacts with the invading Whites, who, too, left relics of their presence. The technique utilized in the Southwest and elsewhere, has been the result of work by Nelson, Kidder, Kroeber, Spier, and others. It has consisted of attempting to correlate stratigraphic results (usually obtained from potsherds, which are plentiful and reliable in the Southwest) with statistical tabulation of the data in each stratum, thus working toward the establishment of eras for the restricted localities within which each was working. More recently, all the work of these students, and that of later men, such as Schmidt, has gone into the attempt to establish relative chronology for the ruins of more extended portions of the regions in which they have all carried on research, with the result that today there are recognized certain well-defined time-series for the Pueblo and pre-Pueblo peoples. When the question as to the actual length of time involved in any one of these periods is broached, none of these students answer. And this is well,—it is a matter of relative length of deposit, of relative frequency of potsherd type, rather than years. How long does it take to form a refuse heap thirty feet deep? One may indeed hesitate before he replies. It is a direct function of the number of people present, of the extent to which they disposed of material, of the climatic conditions making for weathering or preservation,—of so many unknown quantities that the question cannot be answered.

At the same time, the ingenious work of Dr. A. E. Douglas of the University of Colorado Museum, in utilising tree-rings of the wooden beams in the Pre-Spanish pueblos, and correlating these with tree-stumps of known age by the configuration of the thickness of the rings caused by wet and dry years, may give us even an absolute chronology on which to build. In Mexico among the Maya of Yucatan, the problem is often neatly solved by the records of the people themselves, since they had devised one of the most accurate calendrical systems the world has ever known, deciphered by the intricate and painstaking work of Morley and

Spinden. As for a general chronology for the New World such as we have for Europe, it is a matter for the future. That it will eventually come no one doubts. The finding of Pueblo pottery in Kansas, of the Mexican plumed serpent motif on artifacts in Georgia, and Dr. Strong's work in Labrador all strongly point to comparisons which should go a long way toward a general time-scale. That such a correlation of prehistoric periods, perhaps even without the availability of geological and palaeontological data for close comparison, one made possible through the consideration of material excavated in intensive work from the southern Andes to the upper Mississippi, will be achieved, is certainly not too much to hope for. But, again, when it comes, it will be a relative, not an absolute matter, and the periods will be expressed in terms of their length as compared to one another, and not in absolute values of years.

THE FISHER MOUND AND VILLAGE SITE

GEORGE LANGFORD
Joliet, Illinois

The Fisher locality is situated near the Will-Grundy County line on the south bank of the Des Plaines River, a mile or so above the mouth of the Illinois. It is an elevated spot on a thick limestone gravel deposit overlooking the river. The aboriginal works consist of two "Big Mounds" 60 feet in diameter and 7 feet high. surrounded by 50 "Pits" or saucer-like depressions, ranging from 15 to 35 feet in diameter, and seven "Small Mounds" 20 to 30 feet in diameter and 1 to 3 feet high. All of the mounds are conical. The 1928 explorations in the "Small Mounds" comprise the third phase of work at Fisher's, the two preceding phases being discoveries in the "Pits" and in the two "Big Mounds." For the benefit of those unfamiliar with the Fisher locality, I will give a brief account of work done there prior to 1928.

In 1912, 17 years ago, I tried to interest certain scientific institutions in Fisher's, but without success. I had made test excavations and found human skeletons but not much else. I had a "hunch" that the site would prove interesting, but more than a "hunch" was needed where a large expenditure of money was involved, and the matter seemed to be ended. Until 1922, the field had never been cultivated. That year heavy tractor plowing began and was repeated in 1923 and 1924. The destruction wrought prompted me to dig, for apparently mounds, pits, and all were doomed to obliteration. Then began the first phase of exploration at Fisher's; excavation of the two "Big Mounds." This was in September, 1924. A Hungarian, Albert Tennik, offered to assist me. We worked under great difficulties and it was our intention to do only a limited amount of digging—just enough to learn the culture of one of the Big Mounds.

Unfortunately, this intention encountered an unforseen obstacle. We soon found things that impressed us with their novelty and stuck to our job continually finding things that kept us busy up to the present time.

The two Big Mounds contained 294 human burials and were both stratified into three distinct levels which I call Upper, Mid-

dle, and Lower, the separating seams, apparently old surfaces, persisting unbrokenly. Human burials lay one over another, sometimes four high. The chronological succession of graves was determined by planes of origin assisted by the artifacts and postures of the skeletons. The mounds did not represent only one culture but at least three well-defined.

The Upper Level contained burials of brachys and mesos mostly lying upon their sides. Artifacts were few; notched and stemmed arrowpoints of flint and chert and small clay pots smooth-surfaced and undecorated, made of clay and crushed crystalline rock.

Near the top of the Middle Level were burials of brachys and mesos; some upon their backs, others upon their sides. The clay pots were slightly more pretentious than the ones above, having roughened surface and some attempt at decoration. Notched and stemmed arrowpoints had disappeared, their place being taken by small triangles and slender "drills" of chert. Polished stone was represented by ungrooved hatchets or celts. A carved bone culture and a limited shell culture occurred at this level. In the zone beneath covered by an Ash Layer were large numbers of brachys extended upon their backs. The small triangles, "drills," and celts persisted; the shell artifacts were more plentiful; and there were artifacts of copper; but not many things of bone. The clay pots were more elaborate than those from above, the material as a rule being clay mixed with pulverized shell, and elaborately decorated.

It was the discovery of Lower Level burials that kept us digging until now. We found them quite accidentally, for they lay in pure gravel without the usual soil discolorations, nor could any of the graves be traced upward through gravel into the overlying dark soil. These were crouching skeletons without pots or artifacts—mesos and dolichos—and where one overlay another, invariably the meso was above and the dolicho, or long-head, below. Not until December, 1926, did we finish the two Big Mounds.

The second phase of exploration took us to the "Pits." This was in April, 1927, and a party led by Dr. Fay-Cooper Cole collaborated with us. A large and typical pit was No. 19; over 30 feet inside diameter scooped out of gravel to nearly 5 feet below ground level, the material removed being piled in a high thick bank around the rim. In the center were burned stones, ashes, and charcoal. A sloping path led from center to rim. In and around

it were numerous food-holes about 3 feet diameter and 3 to 5 feet deep. Many of the holes contained ashes, charcoal, clamshells, animal bones, and numerous artifacts of bone, stone, and shell. Broken clay pots were particularly abundant. Not a sign of wooden posts or post hole appeared in No. 19 nor in any of the other pits examined. No doubt they represented some unknown form of habitation.

In March, 1928, we entered upon our third phase of exploration—the Small Mounds. These had been dug into more or less in times past, and we did not expect to find much. Our work in the Big Mounds and around the Pits had yielded traces of post-European occupation, or a "Surface" Level, as I called it, and one of the Small Mounds, as we knew, contained or had contained articles of the White Man's manufacture. This was the Southeast Mound standing apart from the rest at the southeast portion of the site. This mound proved to be of considerable scientific interest.

In 1906, twenty-two and one-half years ago, when Mr. Dan Fisher, owner of the farm, lived there, he gave permission to Mr. Howard Calmer, a friend of mine, to dig into any one mound he might choose. Mr. Calmer invited me to participate, and so the two of us drove down from Joliet Thanksgiving Day morning. The vehicle which transported us was a one-lunged Cadillac with tonneau door at the back. There was a crank at the side to wind up and make the thing go, the technique of starting and its duration corresponding to the freezing of a gallon of ice cream. We of today who are accustomed to the luxury of flivvers on gravel roads, cannot appreciate the difficulties we encountered traversing those 18 miles of mud. It took us 4 hours to reach the mounds.

The task of selecting the one to work upon fell upon me, for some unknown reason, and I chose the Southeast Mound, having observed tiny beads near the mouth of a gopher hole piercing the mound near center. We dug there and came upon a human skeleton lying extended upon its back. At the throat we found a crescent and pendant which we thought to be silver. Glass beads, a painted wooden stick, and objects of iron, bone, and brass were strewn about the skeleton, which lay on dirt two feet below the surface.

Being chiefly interested in things prehistorical, I took no great interest in our discovery. It was too modern to suit me, and the perils of auto travel were a strong deterrent; therefore, I found many reasons for not accompanying Mr. Calmer on a second trip

to finish what we had begun. Meanwhile, some Joliet enthusiasts, hearing of our find, persuaded Mr. Fisher to let them dig, and they did so in the early summer of 1907. There were three of them, and I give their account abbreviated:

"At a depth of about 4 feet we encountered four human skeletons; 2 females, 1 doubtful and 1 a man. One woman wore a fluted silver bracelet. Near the bodies were a small (iron) kettle 4 inches high and 4 inches diameter with riveted patch, a clamshell pierced with 5 holes in a row, a long bone pin pierced at one end, and a leaf-shaped arrowpoint (of flint) 2½ inches long. The man's skeleton had received the lion's share of adornment. On the forehead was a band of silver brooches, each 1 inch diameter, and a silver medallion with 5 holes. A thin rectangular silver plate covered each eye socket, smooth on three edges and serrated on the fourth. On the chest was a silver reliquary, and below that a double-barred cross 5 inches long, in each of whose angles was a pendant Roman cross 1 inch long. Near the waist lay another double-barred cross 8 inches long, and on the stomach a glass mirror 5 by 8 inches. One upper arm bore a large silver armlet; the wrist a silver fluted bracelet. Fragments of a shirt or coat, covered with ½ inch diameter silver brooches overlapping each other, appeared around the upper half of the body."

When I saw these various objects some years later, they had all been scrubbed and the "silver" pieces highly polished. I questioned the excavators on several occasions, trying to find how extensively they had dug and was assured that the work had been done thoroughly and completely. The whole mound had been excavated from top to bottom, and nothing was left.

For many years I took these statements for granted, but having learned by experience that the casual digger rarely goes deep enough, in the early spring of 1928 we tried our luck on this much-excavated mound. First, we went through old diggings and widened the area where the 1907 excavators had met with such success and found the lower halves of two skeletons, a man and woman, intact with only the upper portions disturbed, the bones being scattered through the diggings and many of them green-stained. One male humerus had a broad green band around the upper portion of the shaft, and there were jaws and other bones similarly discolored. The two part skeletons undisturbed lay fully extended 18 inches below ground level. Digging beneath them 18 inches more, we came upon an untouched magma of burned human bones and two elliptical blades of mouse-colored flint.

It did not take us long to clear out all of the 1907 disturbance, for only the central and east portions of the mound had been dug, and not deeply. In the old debris were porcelain beads and green-stained bones, circular buckles, finger rings, ear-rings, and a wrist-band, all of brass; also aboriginal pieces, a pierced shell pendant, bone tube bead, and chert arrowpoint. The east portion of the mound had been excavated to gravel, but no deeper, so we continued downward and came upon three undisturbed skeletons about 3 feet below ground level, lying upon their backs, feet east, heads west. One was a young woman, another an older woman, and the third a man. With the young woman were many small porcelain beads, several brass ornaments, a tin pan, and the remnants of a brass-bound chest with brass lock and two iron keys. In the chest were a pair of scissors, some other iron pieces, a bone implement, and a long wooden pin. The older woman had a green-stained pail and an iron butcher knife. With the man were an iron buckle, 3 brass cones of rolled plate, a bone tube bead, a stone pipe, and two bear canine teeth painted and pierced at the root end. Altogether, we accounted for 25 burials, 15 of which had been undisturbed, and every burial was accompanied by one or more objects of brass or iron besides porcelain beads. The adults, 15 of them, occupied the central area, with 5 infants and 5 older children scattered around the rim portion. Each child had several brass or iron objects, each infant only one; a brass thimble, brass sleigh bell, iron pocket knife, etc. We found no clay pots, animal bones, clamshells, ashes, or charcoal—all common in the diggings of the two Big Mounds. Every adult skull was a brachy, the skeletons being rather small according to White Man's standards.

Some of the skeletons had aboriginal artifacts of bone, stone, or shell, but every one was also accompanied by one or more objects of the White Man's manufacture. It was a purely post-European mound less than 150 years old and not an older earthwork containing intrusive burials. Post-European mounds are not commonly met with; in fact I never heard of one such as we found at Fisher's. Instead of a forlorn hope, we found the Southeast Mound a most agreeable surprise.

We spent the balance of the year, 1928, until fall, excavating the other Small Mounds and found many skeletons, finishing the season with a total of 515 burials in all to date. The Small Mounds were lacking in clay pots and artifacts, although they contained grit-tempered potsherds, the ornate shell-tempered variety

so common in the Pits but entirely lacking in the Middle Level of the two Big Mounds. Except for the post-European mound described, all were pre-European. Several belonged to the Upper Level, and two contained Lower Level graves beneath the concealed gravel burials, appearing unexpectedly as in the two Big Mounds.

One of the Small Mounds yielded three forms of interment hitherto unknown upon the site. These were crouching tied, bundled, and scaffold burials.

At one point between two pits was a circular eminence scarcely one foot high. It could hardly be called a mound, and yet it contained many skeletons, the center being given up to a bone mass representing nearly 40 individuals. The spot was overlain with camp debris and pierced with numerous holes 2½ to 3½ feet in diameter and 4 to 5 feet deep. No doubt these were places for food storage, filled in later with dirt and ashes and some relics of bone and shell. Some of them had disturbed the burials beneath. This was the only small mound containing copper implements and shell-tempered potsherds. Such skulls as we found in the intrusive bone mass were brachys which may be correlated with the Upper Level of the two Big Mounds. The food-holes and many of the deeper skeletons were of earlier origin, probably Middle Level. Deeper down we found several concealed burials of mesos, these being much the same as in the two Big Mounds.

The Fisher locality is unique, and its cultures—two at least—have large and varied representation. The mounds show the burial customs of the people, and the pits give mute evidence of how they lived. Both the mounds and pits have yielded their clay vessels and implements in abundance. The numerous skeletons give information of the people themselves.

The Fisher locality is not showy, nor does it possess showy relics. The ceramic work is one of its most attractive assets. The two Big Mounds yielded over 75 clay pots; the pits an enormous quantity of sherds, many of them large sections sufficient to visualize them entire. More than one culture is represented. The bonework comes next in the number and variety of its pieces. There are beamers, or skin-dressers, cut from deer and elk foot-bones, long pointed pins with shovel-like heads, awls, gouges, perforators, sharpened splinters, cut and perforated toe bones, braid rings, and many other artifacts—all cut from bones of elk and deer.

Antlers also were much used, the tips being fabricated for flakers, arrowpoints, game pieces, celts, and various tools. The large incisor teeth of beavers were made into chisels and small beamers. Limb bone shafts of raccoon, wildcats, and dog served as tubular ornaments. Canine teeth of bear and dog were pierced for personal adornment. Bird bones furnished material for tubes, beamers, gouges, and beads. We found bone rods, long needles pierced at one end, curved fish hooks, notched pegs, carved circular wafers, small multi-barbed fish spears, and larger harpoon heads. The two Big Mounds were not lacking in bone culture, but the great bulk of specimens came from the food-holes in and around the pits.

The shell work is primitive, and yet we found several attractive pieces—carved pendants, one of them shaped to represent a fish. Some of the human burials were adorned with shell pendants; one with shell beads. River clams supplied the material, and their shells were to be found everywhere. Some food-holes contained large caches of them. Many had been used as scrapers, and others had been notched and trimmed to serve as spoons. Of marine shells, we found only three small ones, buried with long-heads in concealed graves.

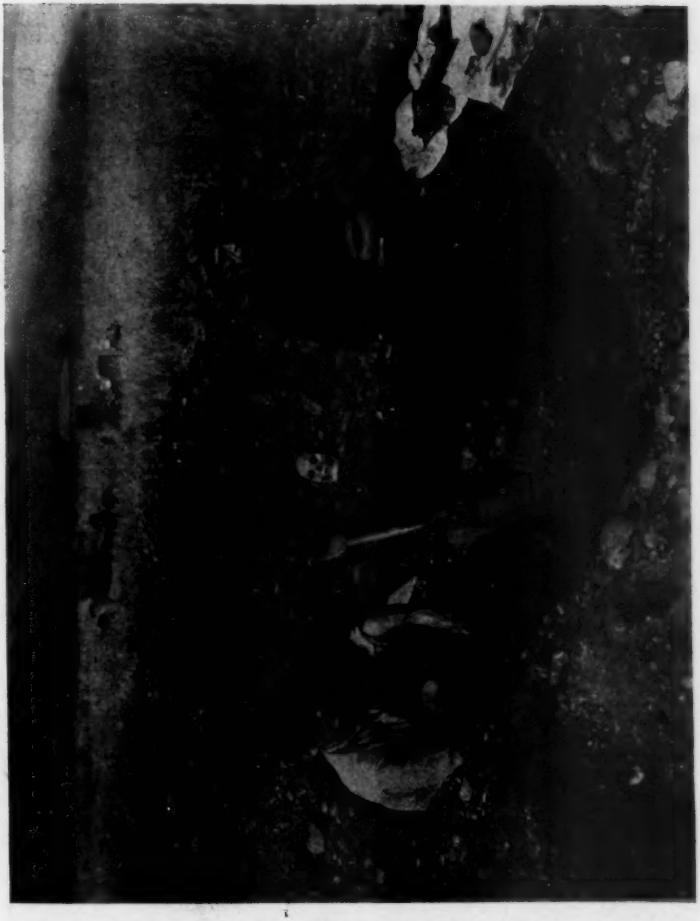
None of the pre-European cultures possessed metal other than copper, and that occurred sparingly, mostly with burials of the Middle Level, as celts, bead necklaces, ear discs, and other pieces.

Chipped flint and chert artifacts were confined to arrow and "drill" points. Notched and stemmed forms from 1½ to 2 inches long appeared to antedate others from the Middle Level where small and thin triangles prevailed, together with long and slender pieces. It is a modest assemblage, there being no large or showy specimens. This is also true of the pecked and polished stone work. The ungrooved hatchet, or celt, is common. We found fine stone pipes, of simple form, around the pits, but none in the mounds. Anvil, hammer, grinding and pecking stones occurred frequently, but no elaborate pieces such as bird-stones, plummets, tubes, gorgets, butterflies, or the like. Bones of animals, birds, turtles, and fishes occurred in great quantity. Occasionally, in the pits, we came upon the skeletons of children partially buried by charred bone, stone, and shell artifacts lying upon them. Sometimes the burned implements were not with skeletons but by themselves. The tribes of Indians which occupied the site from time to time appeared to have a low order of civilization devoid of

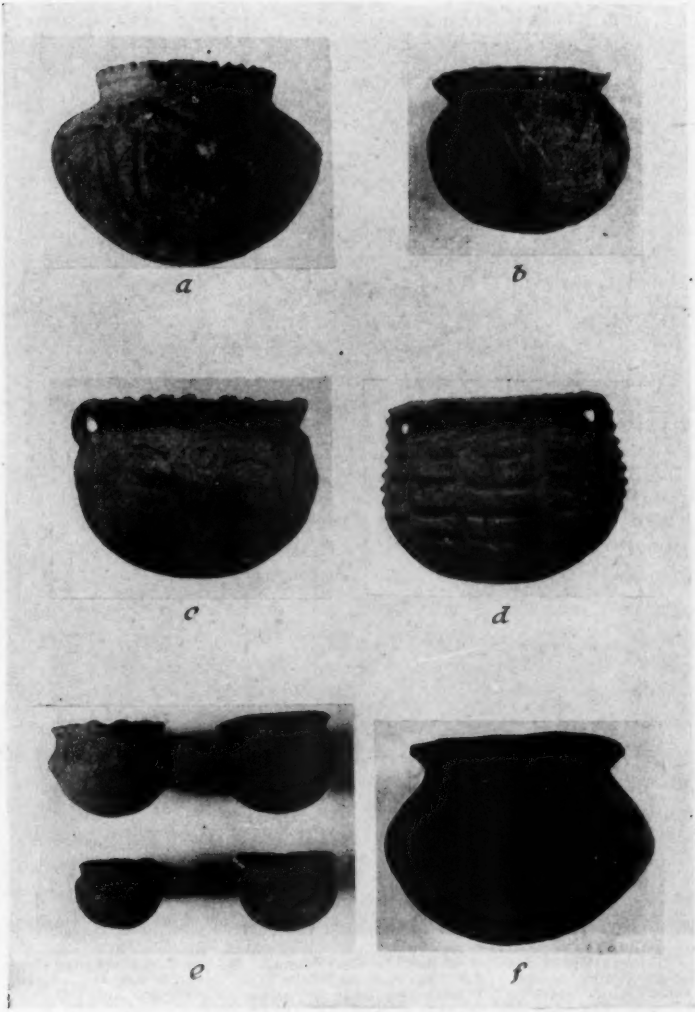
aesthetic sense, and they lacked either opportunity or inclination to do much more than make a living. Simple as they are, the Fisher cultures are full of interest, and the variety and abundance of material in this one restricted locality will be useful for comparing with and defining other cultures. In this respect they may be of assistance in unravelling the human prehistory of northern Illinois. Not only has my work been a great source of diversion and recreation to me, but it has brought me into contact with professionals—fine men and new friends. Although not of the cloth, I can understand them and work in harmony.

ACKNOWLEDGMENT

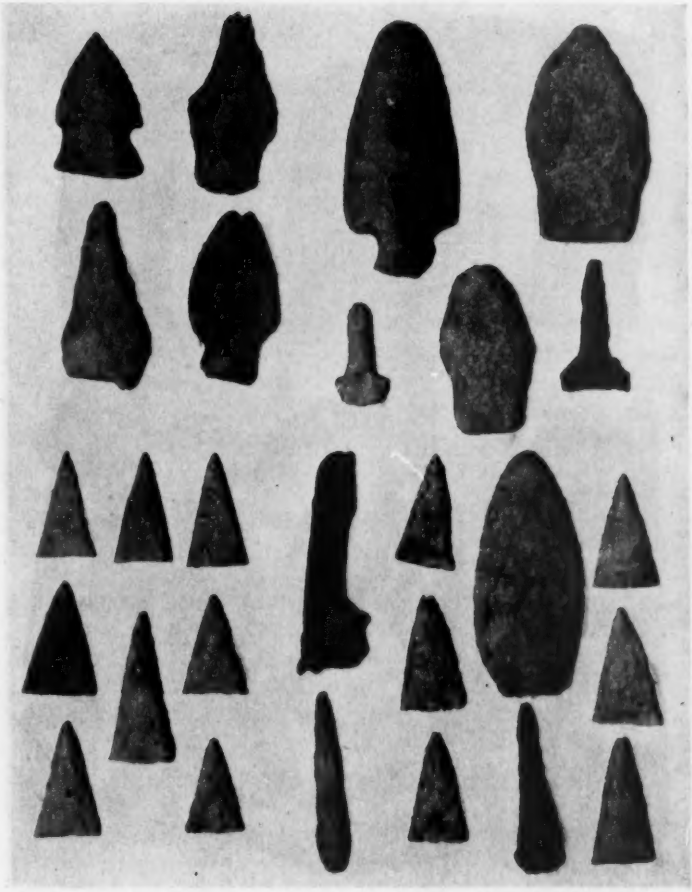
The following plates have previously appeared in the American Anthropologist, Volume 29, July-September, 1927.



Excavation at the rim of the Big East Mound. George Langford standing; Albert Teunik seated. The Big East and Big West Mounds are the nucleus around which the small mound and large saucerlike depressions or "Pits" are grouped. The Big East Mound is about 60 feet in diameter and 6 feet high; the Big West Mound slightly larger. Both were packed with human burials frequently accompanied by clay pots or implements of stone, bone, copper, and shell.

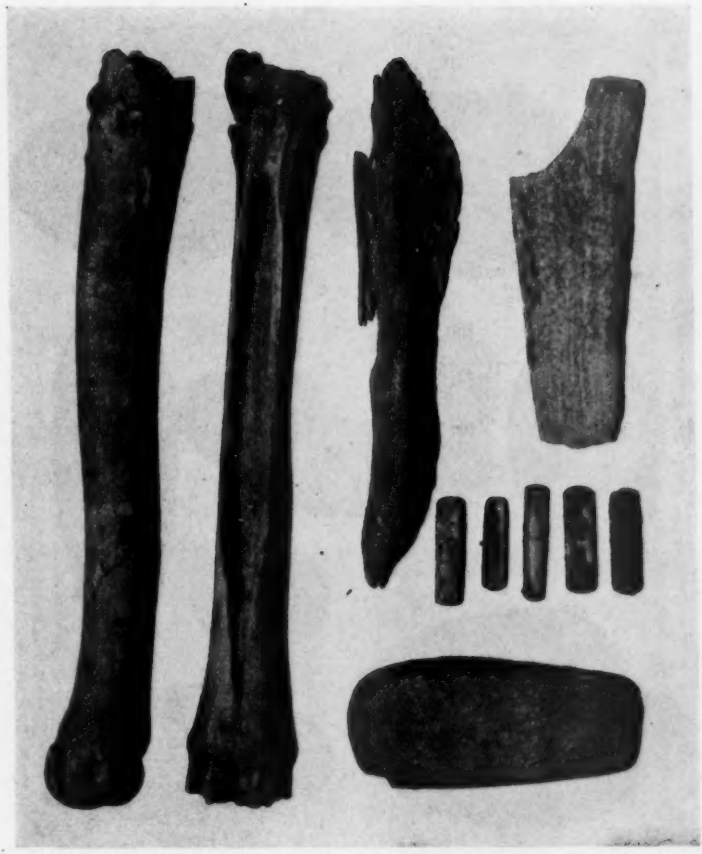


Clay pots from the Two Big Mounds. (About one-fourth actual size.) FIGS. *a-d* inclusive are made of shell-tempered clay and bear "antler-point" decoration. FIG. *a*, with its broad loop handles and dot-and-diagonal decoration, is typical of the Middle Level pottery. FIG. *f*, made of rock-tempered clay, is more recent, as are the four small pots grouped under FIG. *e*.



Chipped stone implements from the Two Big Mounds. (About three-fourths actual size.) The upper nine notched and stemmed forms are from the Upper Level; those below, from the Middle Level. In the center is a human metacarpal bone of the hand with a small triangular arrowpoint embedded in the base.

Copper from the Two Big Mounds. (About three-fourths actual size.) Celts or hatchets, ear discs, bead necklaces, and plate cones. The copper nugget shown at right was with a human burial.



Bone implements. (About two-thirds actual size.) The two long pieces are "beamers" or skin-dressing tools made from the metatarsal bones of a deer. They and the other two utilized bone objects at top of plate accompanied a human burial. The stone tablet and five bone cylinders were buried with a woman. Other skeletons of women were accompanied by similar combinations of stone tablets and bone cylinders. The "Pits" yielded an abundant and varied bone culture.

Shell implements. (About three-eights actual size.) The two figures at the top and the one at the lower left corner are shell spoons. Nearly every clap pot contained one. Three neck pendants and two utilized pieces are also shown in the picture.

PAPERS IN BIOLOGY AND AGRICULTURE

EXTRACT FROM THE REPORT OF THE CHAIRMAN

The following papers were presented at the meeting of the Biology and Agriculture Section in addition to those submitted for publication.

"The Ecology of the Mosses in the Grand de Tour Region with Special Emphasis upon their pH Relationships," by C. E. Montgomery, Northern Illinois State Teachers' College, DeKalb.

"Life History of a Pseudophyllidean Tapeworm," by Lyell J. Thomas, University of Illinois, Urbana.

The chairman of this section for the next meeting is A. R. Kienholz, University of Illinois, Urbana.

E. L. STOVER, *Chairman.*

THE 1926-27 FLOODS AND THE ILLINOIS RIVER VALLEY VEGETATION

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Probably all readers of this article will well remember the heavy and continued rainfall which began during the first week of September of 1926 in the central United States. Within two weeks the tributaries of the Mississippi River and particularly the Illinois River had reached a stage comparable to floods of 1922, 1904, and 1884. The flood of 1926-27, however, proved to be entirely different from preceding floods if we are to judge by the unusual effect it had upon the river valley flora. The principal and immediate difference was in its duration and re-occurence, its history running somewhat as follows:

The high water of September persisted until December, when there was a subsidence which was followed by more hard rains and high water in January, lower water in February and March but a third rise in April, which persisted until the middle of June.

Levees broke and leveed districts were flooded; unleveed, unprotected areas in the river bottom were under water or covered with ice almost all winter. At about corn-shucking time many ranches were covered with just enough water to allow the wild ducks to swim about in the corn fields and pick the corn to the cob on the upright stalks without straining their necks the least bit. The flood was no hardship for the ducks, but it was for the farmers. Preceded by the rabbits, quail, coons, possums, and other ground-inhabiting animals, the farmers waded out to the nearest levee or high ground, camped there, and waited for the water to move out.

The plant inhabitants of the valley were even less fortunate. Anchored to the spot, they had to stay and see it through. The high waters of early fall and of the winter were probably not so destructive, but the persistent submergence of the spring and early summer finished a great many. Total or partial submergence during this critical period, the blossoming and foliating time, was too much for many plants. Very few trees and shrubs profited by the unnecessary wetness. The majority were probably injured in some

FIG. 1. Pecan forest, June, 1927, as water was leaving.

FIG. 2. Dead trees east of LaGrange Locks, August 1927, killed by alluvial soil.

way, and many were killed. In regions where there was not too much alluvial soil deposited with its subsequent smothering effect, the larger, better-established trees of most species survived, bearing sickly, pale, poorly-colored leaves all summer as a remembrance. This, however, was not entirely true of all regions. Above and near the LaGrange locks and dam, hundreds of acres of pin-oaks, elms, and cottonwoods were killed. Estimates made in this region indicate 90 per cent mortality of the species mentioned. Cottonwoods in particular seemed to be easy victims. In the lower end of the river valley, pecans, some of the few walnuts found there, and a few maples were killed, generally the smaller trees, those not exceeding fifteen feet in height. In general, maples, elms, and ash were indifferently affected and the ever-present "elbow-brush" seemed to be infatiguable.

The herbacious growth was temporarily annihilated, but it was re-established within seven days after the water was gone, due to the numerous water-resisting seeds buried in the mud. Maple and cottonwood seedlings were soon apparent and abundant. This ability to successfully re-seed, or re-plant, seems to be a big factor in the control of distribution or the determination of existence in valley flora.

The influence of deposited soil has been mentioned. Deposition of alluvial soil ranged from a few inches to two feet in depth. Large trees, well adapted to the numerous vicissitudes of river-valley life, failed to withstand this. Numerous examples were witnessed, both in the Illinois and Mississippi River valleys, of high mortality in honey locusts, pin-oaks, and even elms and maples, caused by this addition of soil over the roots.

The whole affair illustrates the tragic but interesting struggle for existence of the river valley plants. It seems that the fittest cannot alone be characterized as those that can withstand the emergency but also those that can stage a comeback through their living descendants.

NOTES ON THE ALGAE OF COOK COUNTY

SISTER MARY ELLEN O'HANLON
Rosary College, River Forest.

Among the numerous and various species of algae which abound in the ponds, ditches, and sloughs in the vicinity of River Forest, a few forms have been of particular interest.

In June, 1923, a small pond, at that time apparently more or less permanent, near Palos Park in the Cook County Forest Preserves, offered some especially attractive material. Three successive visits were made to this pond in the month of June that year, and quantities of material representing many genera of the Cyanophyceae, Chlorophyceae, and Diatomaceae were found. Fruiting plants of Oedogonium, Bulbocheate, Zygnema, Mougoetia, and several species of Spirogyra were included in the collections. One species of Spirogyra (fig. 1) seemed to resemble the plant described by Miss Merriman in 1921 and which she called *Spirogyra rectispira*. With respect to the arrangement of the chloroplastids, this plant seems to correspond with Miss Merriman's description.

At the same time an abundance of fruiting *Mougoetia mirabilis* was found. This plant as we have identified it, was found by Wittrock in 1872, and his figures are reprinted by Oltmanns. As reported and figured by Wittrock, the plants found at Palos Park were conjugating, some of the filaments by the scalariform method only (fig. 2), many more by the lateral method only (figs. 3 and 4), and there was not a little of the material in which many of the filaments participated in both types of conjugation (fig. 5). The material was fruiting so profusely as to form a perfect network and exhibited many bizarre and irregular forms (fig. 6-13), among them (fig. 13) twin or, possibly, parthenogenetic spores.

In looking over the literature, particularly that which is less recent, it seems that this plant has been paraded under several different generic names and that a number of species have been distinguished, with differences, especially those based on the methods of conjugation, which can probably all be reconciled in this single species. Borge, however, in 1913 resolved the whole of the family Mesocarpaceae into a single genus (nur eine gattung") and this genus is Mougoetia. Fremy reported this double method of conjugation for *M. capuciana* in 1924. Aside from this and Wittrock's

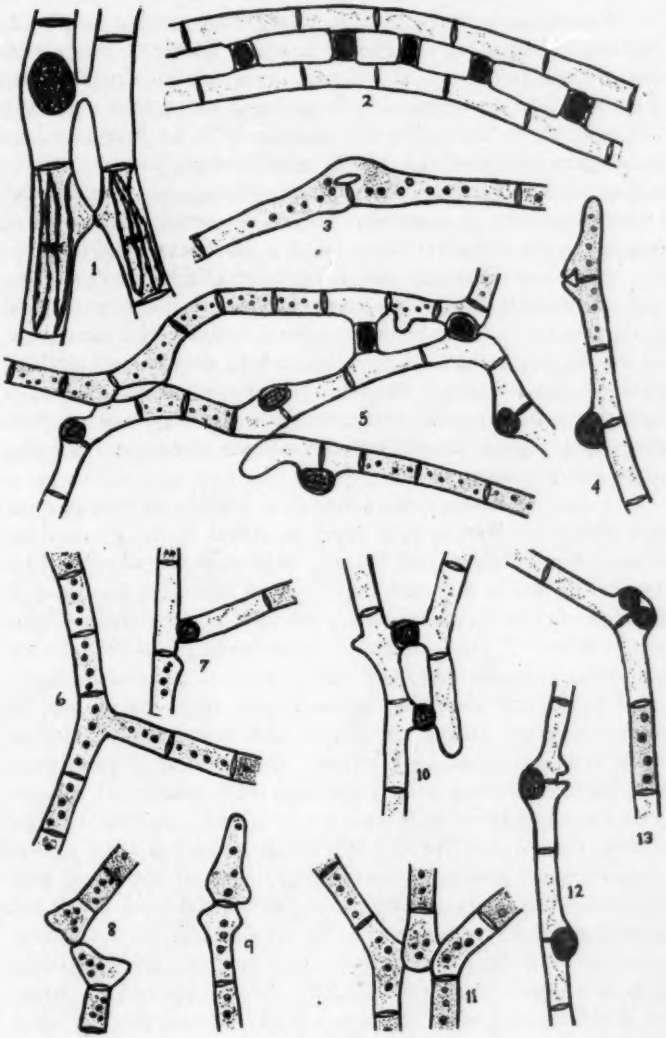

Plate I.

report for *M. mirabilis,* there seems to be no other written account of the two kinds of conjugation in a single filament.

Neither since nor before June, 1923, have we ever found conjugating Mougoetia, although vegetative material has always seemed plentiful enough at different times in a number of places. We returned in the autumn of the same year to the pond where this was collected, to find only sterile plants, and in the following June to be again disappointed but to be repaid for our pains by making a splendid collection of *Volvox globator* which was growing in immense quantities. A subsequent visit to this pond which promised so much to the student of Algae found it practically dried up.

The genus Vaucheria which fruits plentifully in the spring and sometimes in the autumn in the Chicago region is represented in the locality of River Forest by several forms. Two varieties of *V. sessilis, V. geminata, V. terrestris* and *V. macrospora* have been collected (figs. 14-18a). *Vaucheria terrestris* (figs. 18 and 18a) is quite common on muddy flats, growing with Botrydium which is also very abundant especially in the autumn along the wet banks of the Des Plaines River.

In looking through the material, a number of irregularities were observed. Markle, in a paper published in the Proceedings of the Indiana Academy of Science, 1918, describes abnormalities observed by him in different plants, among them, the reproductive branches of *Vaucheria geminata.* We have found similar irregularities in both *V. geminata* and *V. terrestris* (figs. 19-20). In the late winter and early spring of 1928, *Vaucheria geminata* was collected in a ditch about ten minutes walk from the campus of Rosary College. Among the plants were found many branches which were parasitized by a rotifer. In this kind of parasitism, the animal enters the actively growing plant, usually at a point where a potentially sex branch has begun to grow. Normal development of the plant is arrested by this stimulus, and there results a hypertrophied growth not unlike a gall. Contributions of protoplasm from considerable lengths of the filament upon which the parasitized branch is borne, serve as nourishment for the parent animal and the entire brood of young, which numbers sometimes up to as many as forty or more. This phenomenon of gall formation doubtless most often occurs in the way we have just described (fig. 21), but it seems not unlikely that the tip of a filament in which there is the possibility of the development of a zoospore may also serve as host material for the parasite (fig. 25).

The germinating oospore or zoospore, whichever figure 26 may be, also adapts itself to gall formation. Probably all the parasitized material in our collection was that of *Vaucheria geminata* which figure 27 proves conclusively. Miss Rose Kerber in an unpublished paper on the Algae of the Chicago region described this parasitism in *Vaucheria sessilis*. The plants collected by Miss Kerber were found in the autumn.

This relation between Vaucheria and the Rototoria may or may not be common; little about it, however, was noted in the literature. An instance of it in *V. dichotoma* is cited by Heering and the following statement is made in British Freshwater Algae by West and Fritch: "The threads are sometimes subject to the attacks of the rotifer, *Notomata Werneckii* which produces irregular gall-like swellings."

The conclusion is that a number of species, possibly all of the Vaucheriaceae, may respond as hosts to the Rototoria, and that any part of an actively growing thallus in which there is a sufficient food supply, whether this be a developing sex branch, a zoospore formation, or such organs as germinating oospheres and zoospores, may, if stimulated by the entrance of a rotifer, develop into a gall.

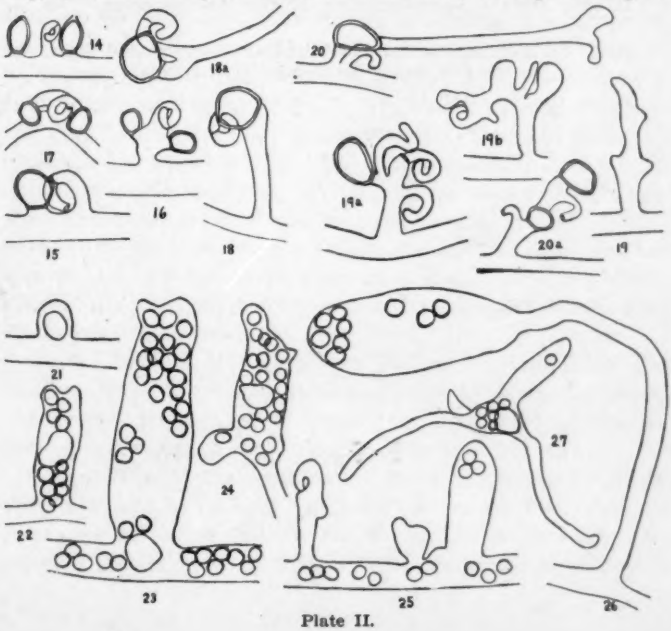

Plate II.

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DOES HIGH TEMPERATURE IN A FRIGID COUNTRY LIMIT DIVERSIFICATION OF THE SPECIES?

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In a warm starch-waste water ditch flowing from a corn products manufacturing plant, located in the northeastern part of Decatur, Illinois, two conditions are quite apparent:

(1) Particularly on cold days, the water in this ditch seems to be steaming. That is, the water vaporizes rapidly and on days when the temperature difference between the air and the water in the ditch is the greatest, the steaming of the warmer water of the ditch is the most extensive. This stream runs under ground for about 2,700 feet in a 60-inch concrete pipe. This empties into a concrete channel (Fig.1) about 160 feet long and 15 feet wide, having 10 baffles along the sides, 15 feet apart. The waste leaves the channel through an 18-inch slot in the center of the last baffle, having a fall of about 15 inches onto a concrete apron about 18 feet long, and then into an open ditch varying in width from 10 to 15 feet. Throughout the entire length are 24 loose concrete block-barriers over which the water falls for the purpose of cooling and aerating it before flowing into the lake. Since the ditch was constructed, erosion has taken place to a considerable extent, until it is now so wide and deep that one cannot cross it by a single jump or remain dry-shod if attempting to wade it. At its confluence with the city's reservoirs (into which it flows), a delta has been built up by the eroded elements. At this place the stream divides into two forks and flows around the delta and then joins the water of the reservoir.

(2) Upon looking closely at the water in the ditch, one notices a super-abundance of fission fungi (*Sphaerotilus natans* and related species), slime algae (*Oscillaria prolifica* and *O. limosa*) and the pond snail, *Physa gyrina* Say (Fig. 2).

Ten stations were established between the beginning of the open ditch and its confluence with the lake or reservoir. Samples of the less putrescent sludge at the top surface of the sludge were collected at different times from these places during December

(1928), January and February (1929) and microscopic study made to determine the quality and approximate quantity or organisms living in this ditch.

It was soon found that only the upper stratum of the sludge, about 2 inches deep, contained organic life (save, of course, bacteria). Neither the flora or fauna is very extensively, qualitatively differentiated. Three species, however, one animal and two plants, live in such an abundance in this ditch that all others are quite trifling, comparatively.

The fission fungus (*Sphaerotilus natans*) is present as floating, flocculent sludge, as a growth covering the entire bottom, sides of the banks, the stones or concrete blocks of the dams and on every twig or blade of grass protruding from the banks out on the water's surface, and as a decaying, black mass forming a sludge bottom, more and more septic the deeper down. The other plant is two species of slime algae, *Oscillatoria (Oscillaria) prolifica* and *O. limosa*. *O. prolifica* seems to be more primitive than *O. limosa* because it is smaller and less green. *O. limosa* gives a green tinge to the condenser water on sunny days, so numerously does it grow on the top of the sludge in the bottom of the ditch. On the sides, nearly pure cultures of this species occur in definite green patches. Mixed with *O. limosa* is *O. prolifica* which is much less green, appearing as gray masses along the water's edge of the entire ditch. But its green color and oscillating movements can be quite easily seen under the microscope.

The animal species, referred to above, is the pond snail, *Physa gyrina* Say, which occurs in countless numbers of all sizes and ages, literally covering every stone and submerged object and the bottom of the ditch, from its beginning to the lake.

It will be noticed that the flora mentioned, particularly *S. natans*, is a sewage organism; these plants live on organic wastes in solution in the condenser water; there is just enough sugar present to promote this, and, in fact, the growth of *S. natans* begins in the warm water near the plant. This is seen by the masses coming out of the concrete pipe at the beginning of the open ditch. The pond snail lives on the luxuriant growth of the slime algae and the fission fungi, noticeably on *S. natans*.

These organisms, then, present a biological feature very striking in contrast with the seemingly unfavorable physical conditions of the ditch, *e. g.*, as shown by the turbidity, musty or earthy odor, and "steaming" high temperature of the water.

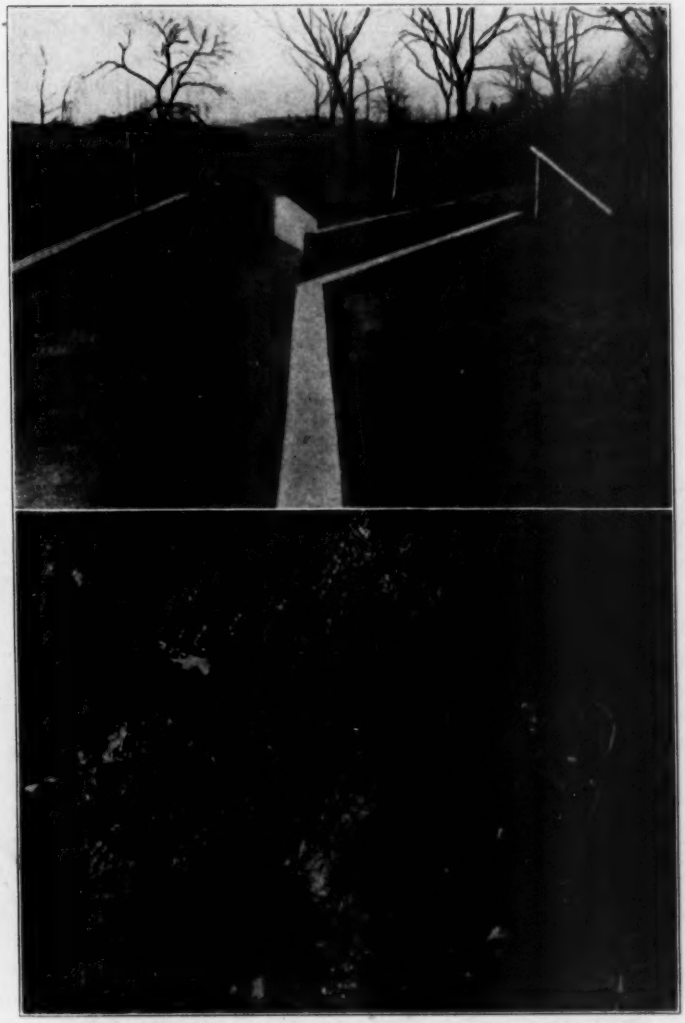

FIG. 1. *(Above).* Photo of the opening of the 60-inch wide concrete pipe, opening into a concrete channel. Note a baffle in the middle-foreground with a slot on the right side. Also note the side-ditch in the foreground and to the right. Station 1 is at the upper left-hand part of the stream, just below the vapor.

FIG. 2. *(Below).* Photo of a typical *Physa gyrina* bed. This snail lives on *Sphaerotilus natans* and *Oscillatoria prolifica*, both of which species abound in the warm condenser water.

The microscopic study of the samples collected from the top of the sludge in the bottom of the ditch at the different stations revealed the following facts:

Station A. From a side-ditch with surface water from half a mile semi-cultivated country (Figs. 3 and 4). The samples were taken beyond the fence, on both sides of the ditch. The season's temperature ranged as far as the fence. The peculiarity of this Station is the total absence of protozoa or lower metazoa. This station, however, may be characterized as belonging to the *Oligosaprobic Zone.* The bottom was composed of fine sand.

There are ten different species of algae as listed below, and the higher of these occurred in clusters along the bottom and around the border of the ditch.

Navicula viridis, Synedra ulna, N. rhynchocephalia, Pleurosigma attenuatum, Meridion constrictum, Gomphonema acumenatum, Vanheurckia rhomboides, Vaucheria repens, Ulothrix zonata, Spirogyra crassa.

Station 1. From the beginning of concrete channel (Fig. 1). The bottom covered with loose flocculent Sphaerotilus sludge. The temperature during the winter ranges around 35° C.

Algae	Fungi
Oscillatoria prolifica + + + + *	*Sphaerotilus natans* + + + +
O. limosa +	
Protozoa	**Metazoa**
None	*Tubifex* + +
	Physa ** +

Temp. of the air,—5° C., of the ditch, 35° C. Dissolved oxygen, 3.2 p. p. m.; 52 per cent saturation.

Station 2. This station is just below the concrete channel, at the beginning of the open ditch proper, that is, 160 feet below Station 1. The temperature at this place was usually only about two degrees lower than at Station 1.

Algae	Fungi
O. prolifica + + +	*S. natans* + + + +
O. limosa +	*Beggiatoa alba*
Cymbella cuspidata	
Synedra ulna	
Brebissonia	
Protozoa	**Metazoa**
Vahlkampfia guttula	Physa gyrina + + +
V. minuta	
Anisonema acinus +	

Temperature of the ditch 33° C. Dissolved oxygen 5.5 p. p. m.; 76.6 per cent saturation.

* The plus-sign has the following meaning: + = quite a few; + + = many; + + + = very many; and + + + + = solid masses, or a super abundance of this species. —= one or very few. ** On the opposite side of the channel, a little below the mouth of the concrete pipe, the water is 1 to 2 degrees lower in temperature and *Physa* may be seen here in quite a number. Likewise, at Station 1, proper at the mouth of the concrete pipe, this snail may be found along the upper edge of the water on the side of the concrete wall.

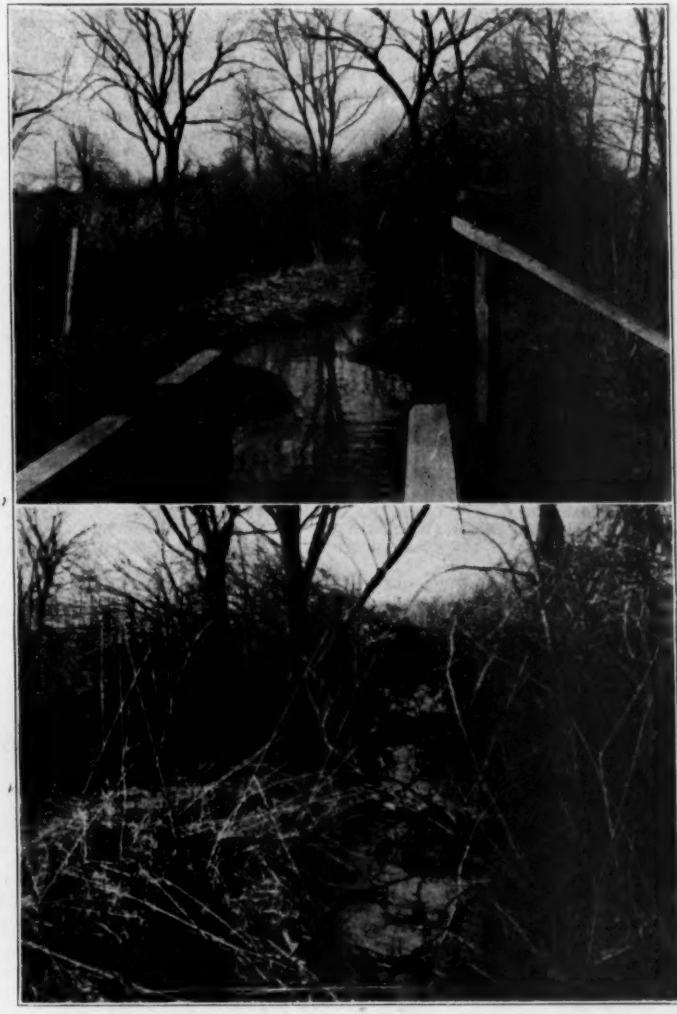

FIG. 3. *(Above).* Photo of the entrance of the side ditch seen in Fig. 1. Station A is just back of the fence.

FIG. 4. *(Below).* Photo of the wet-weather ditch from back of the fence, Station A.

Station 3. This station is just below, and opposite to, a conduit leading from the grain elevators of the manufacturing plant. It is 450 feet below Station 2. In general, the conditions are the same as at Station 1 or 2. An herd of cattle came and drank of the water from the ditch and seemed to enjoy it very much (Feb. 5, 1929). The temperature of the air was—5° C.; of the ditch, 33° C. Dissolved oxygen, 5.3 p. p. m.; 73.9 per cent saturation. There were very many snails present, and the bottom was green and gray from the growth of *Oscillatoria limosa* and *O. prolifica, respectively.*

Algae

Stauroneus anceps
Navicula gracilis
Oscillatoria prolifica + + + +
O. limosa + + +
Genicularia spirotaenia
Microcystis

Fungi

S. natans + + + +

Protozoa

Euglenoids +
Euglena acus
E. viridis
Astasia trichophora
Peranema trichophorum
Physomonas elongata
Amoeboids +
Colpoda campyla
Paramoecium caudatum
Lionotopsis anser
Colpidium striatum
Spirostimum ambiguum
Loxodes rostrum
Metopus sigmoides

Metazoa

Rotifer citrinus
Pedalion mirum
Dero limosa
Tubifex multisetosus
Physa gyrina + + + +

Station 3A. From grain elevator ditch with white bottom. The sample was taken from the white bottom (top) of the ditch. Temperature of ditch, 8° C., of the condenser water at this point, 30.5° C. The water level was lower than on January 19 and bubbles of foul air came up from the sludge.

Algae

Genicularia spirotaenia
O. prolifica
O. limosa
Mougeotia

Fungi

S. natans + + + +

Protozoa

Hartmanella + + + +
Euglena acus +
E. viridis +
Paramoecium bursaria
P. caudatum
Spirostimum ambiguum +
Colpoda campyla
Colpidium striatum
Trichoda pura
Loxophyllum ornatum
Oxytricha trichogaster

Metazoa

Planaria
Nematode
Rotifer citrinus
Tubifex
Physa gyrina + + + +

Station 4. 650 feet below Station 2. Water more turbid than earlier in the morning. Temperature 32.5° C. *Physa* and *Sphaerotilus* in super-abundance. Both species of *Oscillatoria* are also thick. D. O. 5.4 p. p. m.; 74.6 per cent Sat.

Algae
O. limosa + +
O. prolifica

Protozoa
Hartmanella + + +
Diflugia +
Euglena

Fungi
S. natans + + + +

Metazoa
Physa gyrina + + + +

Station 5. *S. natans* and *Physa gyrina* abound. Temp. 32° C. D. O. 5.7 p. p. m.; 77.8 per cent Sat.

Algae
O. prolifica + + + +
O. limosa + +

Protozoa
Physomonas elongata +
P. caudatum +
Colpidium striatum +
Spirostimum ambiguum +
Frontonia

Fungi
Physa gyrina + + + +

Metazoa
Physa gyrina + + + +

Station 6. 2,000 feet below station 2. Water very turbid and gray. Temp. 31° C. D. O. 5.7 p. p. m.; 76.2 per cent Sat.

Algae
O. prolifica + + + +
O. limosa +

Protozoa
E. viridis +
P. caudatum +
S. ambiguum +

Fungi
Physa gyrina + + +

Metazoa
Physa gyrina + + + +

Station 7. 2,700 feet below Station 2. Opposite the delta in the field near the reservoir. Temp. 30° C. D. O. 6.0 p. p. m.; 78.7 per cent Sat.

Algae
O. prolifica + + +
Stauroneis anceps
Navicula gracilis

Protozoa
E. minuta +
E. viridis +
Monas + +
P. caudatum +
Colpodium striatum
Colpoda campyla
S. ambiguum
Nasula ornata
Metopus sigmoides + +

Fungi
S. natans + + + +

Metazoa
Physa gyrina + + +
Gizzard-shad + + +
Carp + +
Bullhead
Chub
Minnows
Sunfish
Bluegill
Kingfisher
Craw + + + +
Larus + + +
Mallard

Station 7A. About twenty paces to the east of Station 7 where the warm water of the starch-waste water ditch mingles with the seasonal cold water of a cold water ditch. Temp. 1° C. D. O. 12.8 p. p. m.; 90 per cent Sat. Gizzard-shad and other fish passing into this cold water from the warm water die in it, owing to lack of gill function. The water is clear. The rest of the biota of this cold water gives an entirely different picture from that shown by the warm water and indicated for the various stations, given above.

Algae

O. prolifica
O. limosa
Synedra ulna
S. pulchella
Navicula gracilis
Cocconema
Pleurosigma attennuatum
Nitzschia linearis
Melosira varians
Asterionella gracillima
Spirogyra crassa

Fungi

S. natans + +
Clonothrix
Cladothrix
Zoogloea ramingera

Protozoa

Chlamydomonas
Trentonia flagellata
Cryptomonas ovata
Dexiotricha plagia
Oxytricha

Metazoa

Pedestes saltator
Physa gyrina +
Gizzard-shad + + + +
Carp + +
Bullhead catfish
Chub
Minnows
Sunfish
Crappie
Bluegill
Turtle (snapping)
Kingfisher
Crow + + + +
Larus + +
Mallard duck

Station 8. In the field below the delta by the junction of the bay reservoir. Many dead carp on the shore after receding water, and dying gizzard-shad. Temp. 29° C. D. O. 6.6 p. p. m.; 85 per cent Sat.

Algae

Navicula gracilis + +
Stauronsis anceps + +

Fungi

S. natans

Protozoa

Small amoebae
Euglena minuta +
E. viridis
Holophrya
Spirostimum ambiguum
Paramoecium caudatum
Holosticha vernalis
Chaenia teres

Metazoa

Rotifer critinus
Physa gyrina

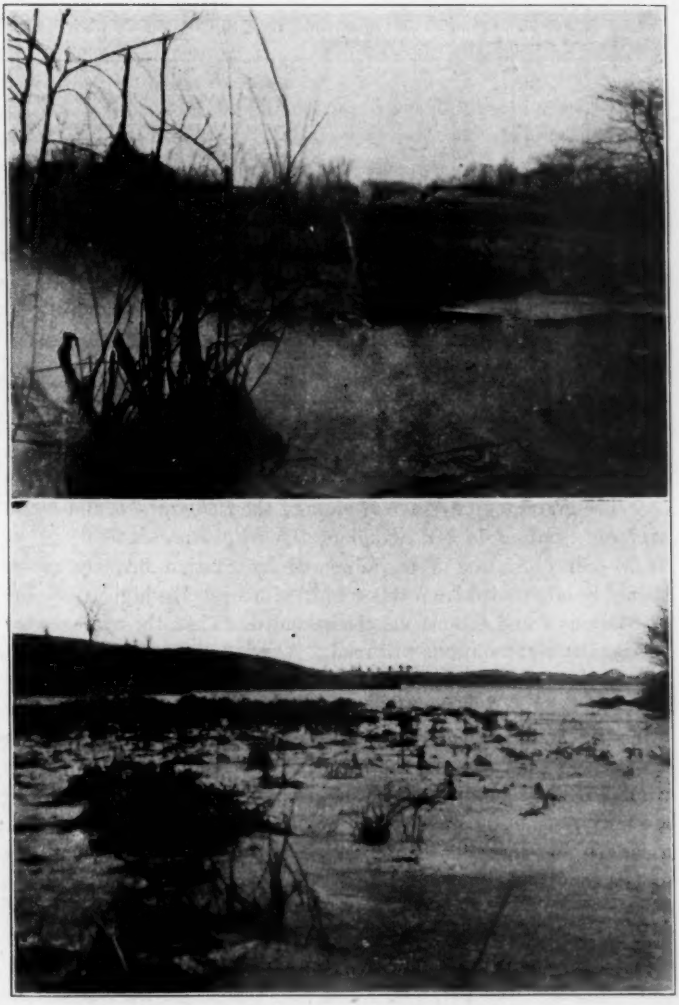

FIG. 5. *(Above).* Photo showing the confluence of the warm condenser water ditch (left) with a cold water ditch (right). Note also the ice sheet. The mixed water flows south, in the foreground of the picture. This represents Stations 7 (to the left in the "steaming" portion) and 7A to the right (in front of the ice).

FIG. 6. *(Below).* Photo of the marsh-land bay south of the mouth of the condenser water ditch, facing south and showing the main part of the bay. Lake Decatur is beyond the point.

TABLE I. NUMBER OF KINDS OF ORGANISMS AT EACH STATION

Station	Algae	Fungi	Protozoa	Metazoa	Zone
A	10	0	0	0	Oligosaprobic water and bottom.
1	2	1	3	2	Polysaprobic bottom, water mesosaprobic.
2	4	2	3	1	Polysaprobic bottom, water mesosaprobic.
3	6	1	14	5	Mesosaprobic water, polysaprobic bottom.
3A	4	1	11	5	Polysaprobic bottom, water alpha-Mesosaprobic, judged by the metazoa there.
4	2	1	3	1	Polysaprobic bottom, top, alpha-Mesosaprobic, judged by presence of Physa.
5	2	1	5	1	Polysaprobic bottom, top, alpha-Mesosaprobic, judged by presence of Physa.
6	2	1	3	1	Polysaprobic bottom, top, alpha-Mesosaprobic, judged by presence of Physa.
7	3	1	9	12	Polysaprobic bottom, alpha and beta. Mesosaprobic; fish struggle in medium.
7A	11	4	5	7	Oligosaprobic; temperature difference kills fish.
8	2	1	8	13	Alpha-and beta mesosaprobic merging with Oligosaprobic Zone.

	Algae	Fungi	Protozoa	Metazoa	Total average Algae and fungi	Total average animals
Average of all stations except A and 7A, which are Oligosaprobic.....	3	1.1	6.44	3.44	2.05	4.88

The grand total average of biota of the *Polysaprobic* and *Mesosaprobic* Stations is 3.467, and of the *Oligosaprobic* Stations = 18.5. Since Station 3 is influenced by Station 3A, the latter should be eliminated from this count. Moreover, the higher metazoa of Stations 7 and 8 must also be excluded. Then the averages for the regular eight stations will read: Algae, 2.8; Fungi, 1.1; Protosoa, 6; and Metazoa, 1.5.

The conditions described by the terms *poly-* and *mesosaprobic* bring in another factor, so that temperature alone cannot be designed as the cause for the tropicobiotic condition in this frigid clime. It must, however, be borne in mind that the ecological zones are only resembling such typical conditions; they are real only in a certain measure. The water on the top layer of the sludge presents a condition which is better than that for the *beta-Mesosaprobic* zone. Because in all the situations described for each station a typical pond metazoon is present in very large numbers; here it lives, mates, multiplies, abundantly. That means, it seems, the conditions are even advanced above that typical for the *beta-Mesosaprobic* zone. And, yet, although a great amount of food is present, which could support an enormous animal population, very few species, living on this food, are present. This accounts mostly for the formation of such an extensive sludge bed. That is to say, a large number of individuals of a few species which serve as food

(for *Physa gyrina*) are found in the ditch, and only one species (*P. gyrina*) not a member of the *poly-mesosaprobic* zones, is present. There is, therefore, this unmistakable combination of con-

TABLE II—DISTRIBUTION OF SPECIES AT THE DIFFERENT STATIONS

Name of species	Stations								Remarks
	1	2	3	4	5	6	7	8	
Sphaerotilus natans	x	x	x	x	x	x	x	x	Abundant.
Clonothrix							x	x	
Beggiatoa		x							
Oscillatoria prolifica	x	x	x	x	x	x	x	x	Abundant.
O. limosa	x	x	x	x	x	x	x		
Synedra ulna		x					x		
Cymbella cuspidata		x							
Brebissonia		x							
Stauroneis anceps			x			x		x	
Navicula gracilis			x			x	x	x	
Genicularia spirotaenia			x	x					
Microcystis			x						
Mougeotia				x					
Vahlkampfia guttula		x							
V. minuta		x							
Hartmanella				x					
Small amoebae								x	
Amoeba or Amoeboids			x						
Difflugia				x					
Anisonema acinus		x							
Euglenoids			x						
Euglena acus			x						
E. viridis			x	x?		x	x	x	
E. minuta							x	x	
Monas							x		
Astasia trichophora			x						
Peranema trichophorum			x						
Physomonas elongata			x		x				
Holophrya								x	
Colpoda campyla			x				x		
Colpidium striatum			x		x		x		
Paramoecium caudatum			x		x	x	x	x	
Prontonia					x				
Nassula ornata							x		
Spirostimum ambiguum			x		x	x	x	x	
Chaenia teres								x	
Lionotopsis anser			x						
Loxodes rostrum			x						
Metopus sigmoides			x				x		
Holosticha vernalis								x	
Rotifer critinus			x						
Pedalion mirum			x						
Dero limosa			x						
Tubifex multisetosus	x		x						
Physa gyrina	x	x	x	x	x	x	x	x	Abundant.

ditions: one represented by the pollution environment which excludes all forms save the typical pollution (*polysaprobic*) organisms; the other, by the high temperature, semi-pure water, and freshening super substratum of oxidation activity in which two chlorophyllaceous organisms (*Oscillatoria prolifica* and *O. limosa*) participate.

By Table II it is seen very graphically that Station 3 is influenced by Substation 3A (Compare biotae of these stations.) This may mean that the samples collected at Station 3 are not typical for the entire ditch, hence Station 3 is not typical for the ditch as a whole. The conditions, otherwise, are quite uniform. *P. gyrina* is well adapted to the conditions of the ditch, but apparently no other typical fresh-water forms. Probably high temperature is the factor controlling this.

At Stations 7 and 8 a number of fish enter the water of the ditch where it joins with the lake. But they have a hard time of it, especially when the temperature of the water changes suddenly, as shown by instances when fish accidentally enter cold water with the season's temperature and with nearly three times the amount of dissolved oxygen. The gills fail to function; in consequence the fish die in a short time. Likewise in the outer bay, when the water is by-passed cold at the plant, the fish die also there; while in the warm water (29 to 26° C.), the fish have a hard time of it. They die from the high temperature, the gills having ruptured. Hence the fish fauna cannot be taken as a normal population of the starch-waste water ditch. It may therefore be said with quite certainty that the high temperature in a frigid country limits the number of species which can live continuously and maintain themselves by reproduction in a given situation.

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A STUDY OF THE POLLUTION OF THE BIG MUDDY RIVER SYSTEM

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State Department of Health, Springfield.

During the summer of 1928 a detailed study to determine the character, amount, and effect of pollution of the Big Muddy River system was made jointly by the State Departments of Public Health and Conservation. In brief, the investigation was made because of repeated complaints received by both departments relative to the destruction of fish life and the increasing difficulty on the part of several municipalities to obtain a satisfactory and safe water supply from the river. The need for the investigation is reflected by the formal resolution which was passed by the city council of Murphysboro and addressed to the State Department of Public Health, requesting that the necessary studies be made.

During the course of the survey, detailed investigations were made of the pollution tributary to the nine principal tributaries of Big Muddy and the Big Muddy from its source to its mouth. The work comprised an accurate physical survey of all sources of pollution in the entire watershed with reference to the character, amount, and point of entrance of such pollution, routine physical observations of the effect of such pollution along all critical stretches of the tributary streams or river, and repeated chemical and biological studies at numerous convenient and strategical stations established along the various watercourses.

This paper will be restricted to a generalized discussion of only a few representative situations which are typical of the general information acquired for the entire system and which, because of their biological significance, should be of some interest to the members of this section.

SELF PURIFICATION OF REESE CREEK

Reese Creek rises in the vicinity of Tamaroa, flows southerly for a distance of about 7 miles to a point near the northeast corner of DuQuoin and thence easterly and south easterly for about 7 miles to its junction with Little Muddy River.

Above DuQuoin the creek is subjected to only the casual pollution produced by the rural inhabitants of the watershed. Near

the northeast corner of DuQuoin and about seven miles above its mouth Reese Creek receives the combined wastes of the city of DuQuoin and the DuQuoin Packing plant.

The DuQuoin Packing Plant wastes comprise about 5,000 gallons per 8 hours of wash water containing blood, paunch manure and floor washings. The wastes are first treated in two small settling tanks before discharge to the watercourse. The dry weather sewage flow at DuQuoin is about 500,000 g.p.d. which is inadequately treated in a septic tank before discharge. The packing plant wastes enter a small artificial ditch a few feet below the DuQuoin sewage effluent outlet, and the combined wastes which comprise the total flow in this small branch during dry weather, flow north easterly about 1,000 feet to join Reese Creek. At this point the normal flow in Reese Creek is zero and ordinarily only a limited amount of seepage water is available for dilution purposes between this point and Little Muddy River. The stream presents, therefore, an ideal condition for studying the self-purification process. From DuQuoin down stream 3.4 miles, the stream flows in a well defined channel 8 to 12 feet wide and 3 to 4 feet deep. Normally the stream itself flows through a cross section about 3 to 6 feet wide and 0.5 to two feet deep, with a sluggish velocity.

At a point 3.4 miles below DuQuoin, Reese Creek enters what locally is termed "The Scatters", an almost impenetrable swamp overgrown with cattails, pond lilies, marsh grass and other luxuriant aquatic growths. This swamp which normally is fed only by Reese Creek is about ¼ mile wide and 1.7 miles long. Reese Creek emerges from this swamp at the hard road crossing just east of old DuQuoin, 5.1 miles below DuQuoin, and flows about 1½ miles to join Little Muddy.

The various observations present such striking evidence of the self-purification process and the beneficial effect of the intervening swamp, that it seems worthwhile to present the essential data.

Although data are available for three separate investigations of Reese Creek and from 11 different stations along its course, it will suffice to present briefly the conditions existing at three points on July 10, 1928, at which time the flow in Reese Creek above the point of pollution was negligible.

Reese Creek just below point of pollution. Flowing liquid was dark greenish brown, of thick sluggish consistency, containing

much suspended material. Very offensive odors prevailed. Gas bubbling was profuse. Sludge deposits were about two feet deep, black, slimy, offensive, and teeming with white tubifex. Significant analytical results were as follows:

(Results in p.p.m.)

Dissolved oxygen	0
5-day B. O. D.	550
Turbidity	1100
Total solids	2472
Volatile solids	742
Free Am. plus Organic N.	18.4
Nitrites	0
Nitrates	0
Oxygen consumed	321

Reese Creek 2.6 miles below point of pollution. This station is situated 0.8 miles above point at which Reese Creek enters "The Scatters". Flowing liquid appeared black due to heavy black, slimy and offensive sludge deposits. Very offensive odors noticeable 500 feet from stream. Significant amounts of oil on surface. Gas bubbling profuse. Tubifex present in mass growth. Top water minnows entering from small ditch connected with small adjoining pond turn back upon reaching the polluted water. Some minnows were observed to become listless upon striking the polluted water, and those which were unable to get back to fresh water perished in 5 to 10 minutes. Blue-green algae pads abundant on water surface. Significant analytical results were as follows:

(Results in p.p.m.)

Dissolved oxygen	0
5-day B. O. D.	307
Turbidity	75
Total solids	1344
Volatile solids	378
Free Am. plus organic N.	4.96
Nitrites	0
Nitrates	0
Oxygen consumed	68

Reese Creek 5.1 miles below point of pollution. This station is located on Reese Creek immediately after emerging from "The Scatters". The stream at this point would never by appearances suggest the offensive conditions which prevail at the point where "The Scatters" begin. There were no odors. The water was clear and contained many minnows of different kinds. Green algae, green aquatic growths, and fresh water forms of life are abundant. Significant analytical results were as follows:

(Results in p.p.m.)

Dissolved oxygen	6.1	=71% of saturation
5-day B. O. D.	33.5	
Turbidity	0	
Total solids	506	
Volatile solids	180	
Free Am. plus Organic N.	0.2	
Nitrites	0	
Nitrates	0	
Oxygen consumed	15.2	

It is seen that the intermediate station is situated approximately half way between the point at which the wastes are admitted and the point at which the stream appears to be substantially recovered. The upper 2.6 miles of the stream that we are considering has a well-defined channel. The lower 2.5 miles of stream becomes lost in a swamp 1.7 miles long. The changes occurring in the two sections of the stream are of interest when compared in the following table, because the beneficial effect of the swampy portion of the stream in disposing of the wastes is strikingly presented by the high percentage of change occurring in the lower section.

CHANGES OCCURRING IN REESE CREEK

Determinations	(Results in p.p.m.) Upper section 2.6 miles long fairly uniform channel	% change	Lower section 2.5 miles long 1.7 miles in swamp	% change
Dissolved oxygen	0 to 0	0	0 to 71% sat.	.....
5-day B. O. D.	550 to 307	—44	307 to 33.5	—81
Turbidity	1100 to 75	—93	75 to 0	—100
Total solids	2472 to 1344	—46	1344 to 506	—62
Volatile solids	742 to 378	—49	378 to 180	—52
Free Am. plus Organic N	18.4 to 4.96	—73	4.96 to 0.2	—96
Oxygen consumed	321 to 68	—79	68 to 15.2	—78

ACID CONDITIONS IN BIG MUDDY TRIBUTARIES

Crab Orchard Creek, Hurricane Creek, and Pond Creek enter Big Muddy at points about 10 miles apart, along the most critical stretch of the river. A summary of the most important pollution reaching these tributaries follows:

	Crab Orchard	Hurricane	Pond
Mine wastes	400,000 g.p.d.	4,000,000 g.p.d.	10,000,000 g.p.d.
Raw sewage	1,200,000 g.p.d.	1,000,000 g.p.d.	
Partially treated sewage			500,000 g.p.d.
Creosote wastes	125,000 g.p.d.		

The mine water is that which is pumped from workings and usually is strongly acid. In some mines the water is so strongly acid that pipe lines are renewed weekly.

Determination of hydrogen ion concentration were made at 8 different stations on Crab Orchard on several different days. Values of pH=6.0 to 6.8 were usually recorded for the stretch between Carbondale and Marion, although on July 26 at a point about ⅓ of the way between Marion and Carbondale a value of less than 4.4 was obtained. The pH readings reflect a water with a normal tendency toward the acid side with an occasional surge toward strongly acid conditions.

The flow of Hurricane Creek normally is about 80 to 90 per cent acid mine water. Readings at 7 stations on three different dates gave pH values ranging from 3.8 to 5.6. On August 3, samples collected from the stream just before junction with Big Muddy, 1.6 miles above its mouth, and Little Hurricane Creek, gave acidities of 276, 320, and 920 p.p.m. respectively. It is thus seen that Hurricane Creek normally is strongly acid.

The flow in Pond Creek is almost altogether comprised of mine water. pH determinations made at 7 stations on 3 different dates gave values uniformly less than 4.4. On August 29, a sample from Pond Creek before junction with Big Muddy gave an acidity of 365 p.p.m. Pond Creek normally is strongly acid.

Destruction of Fish in Big Muddy River

The section of the river with which we are now concerned is that stretch between Murphysboro and the mouth of Pond Creek. Acknowledgment is here made to Dr. H. P. K. Agersborg of the Department of Conservation who conducted biological studies of this portion of the river and from whose report certain data have been taken.

During the past several years the dying of thousands of fish in the Big Muddy River has been a periodical occurrence. Usually in September or October of each year the fish become listless.

floundering about near the surface, and succumb within 24 to 48 hours. Sometimes this phenomenon occurs twice a year; sometimes it skips a year; but it always comes with comparatively good regularity. And when it occurs it apparently is no small catastrophe for the bloated remains of countless numbers of fish begin streaming down the river, lodging behind drifts and becoming stranded on sand bars. A description furnished by Mr. Albert Spiller, a commercial fisherman of Carbondale, of the conditions during the past two years will be sufficient. Mr. Spiller, whose word is to be taken at its face value, states:

> "In 1927 due to excessive high water, there were more fish in Big Muddy than at any other time since 1899. And when the killing occurred, more fish were destroyed than it is humanly possible to believe could exist in one stream like Big Muddy. The sad thing about it was that about 60 per cent were game fish, mostly black bass, striped bass, and jack salmon or 'wall-eyed pike'. The first three days of October, 1927, Big Muddy was almost white from the dead fish floating down it and it would be hard to estimate how many billions of fish of all sizes were killed. On the sand bars just below Murphysboro, eight or ten wagon loads of dead fish were stranded.
>
> "In October, 1928, thousands of dead fish poured over the Royalton waterworks dam. In many places along the river as many as 50 dead fish (Buffalo, carp, and catfish) weighing between 5 and 50 pounds were floating behind drifts."

On August 13, 1928, conditions at 7 different stations on Big Muddy were no different than on several preceding dates. There were no indications that the waters were approaching a critical condition. The next visit to the routine sampling stations was on August 27 one day after word was received from the Royalton waterworks operator that hundreds of fish were dying in the river. On this date a moderate number of dead fish were observed all the way from Blairsville to Royalton. The Royalton operator stated that conditions had been worse a few days previously. By August 30 the trouble had entirely passed. The analytical results for the period just preceding and following August 27, will be of interest.

It is to be noted that at all times and even on the date that the dead fish were observed there the waters were well-saturated with dissolved oxygen and had comparatively low bio-chemical oxygen demands. On August 13 the water at all stations was

Location	Date	Dissolved oxygen per cent saturation	5-day B. O. D. p.p.m.	pH	Remarks
Plumfield (above Pond Creek).	Aug. 13	71	8.6	7.6	Turbid.
	Aug. 27	78	5.7	7.8	Turbid.
	Sept. 3	92	4.4	8.0	Turbid.
Royalton (below Pond Creek).	Aug. 13	60	10.1	7.6	Turbid.
	Aug. 27	72	5.2	4.4	Very clear.
	Sept. 3	86	2.0	6.0	Clear.
¾ miles east of Bush below (Pond Creek).	Aug. 13	67	5.7	7.8	Turbid.
	Aug. 27	69	4.9	4.4	Very clear.
	Sept. 3	91	3.3	6.7	Clear.
Blairsville (below Pond Creek).	Aug. 13	64	8.3	7.8	Turbid.
	Aug. 27	78	8.8	6.2	Clear.
	Sept. 3	82	7.5	7.0	Fairly clear.
6 miles north of Carbondale.	Aug. 13	54	8.4	7.8	Turbid.
	Aug. 27	76	13.8	6.3	Turbid.
	Sept. 3	75	10.0	6.8	Turbid.
Murphysboro.	Aug. 13	56	9.5	7.8	Turbid.
	Aug. 27	62	21.5	6.6	Turbid.
	Sept. 3	47	7.3	6.8	Turbid.

alkaline as reflected by the uniform pH values of 7.6 to 7.8. On August 27, the day that many dead fish were observed, the water was alkaline above Pond Creek and extremely acid between Blairsville and Royalton. Below Blairsville there was a tendency for the river to recover its alkaline condition although acid conditions prevailed to Murphysboro. On September 3 the pH values had increased considerably although they were still on the acid side. Another striking observation was that when low pH values were obtained there was a striking clarification of the water, which ordinarily is very turbid. At two stations, objects on the river bed could be plainly discerned through a depth of 5 feet. The evidence thus far accumulated would certainly suggest that the phenomenon of fish destruction in Big Muddy is definitely correlated with the acidity of the river waters and occurs when pH values descend to about 4.4. Between October 9 and 13, 1928, the phenomenon was repeated in a more severe manner. Samples collected at the time from Murphysboro and Royalton gave pH values of less than 4.4 at Royalton and 6.0 at Murphysboro.

RIVER SEINING WORK

During the survey under the direction of Dr. H. P. K. Agersborg, river seinings were made at 7 Big Muddy stations and in the principal tributaries. A large 75-foot seine and minnow nets were employed. Not a single fish nor minnow were obtained out of several attempts from Pond, Hurricane, or Crab Orchard Creek. Only slightly better success was obtained for the river stations. The total number of fishes without regard to kind, for each river station examined, is given by the following:

Near Sand Ridge	7
Below Murphysboro	6
Above Murphysboro	19
6 Miles North of Carbondale	8
Blairsville	0
Royalton	10
Plumfield	6

In 1927 Mr. Spiller at the point 6 miles north of Carbondale obtained as many as 500 small bass with one drag of a seine, while engaged in rescuing fish just prior to the severe slaughter already described by him. The seining work was carried on in September following the period when acid conditions prevailed in the river and this may be an explanation of the indicated low fish population.

CONCLUSIONS

While time has permitted only a general glance at two or three interesting situations uncovered by the investigation, the essential facts have been brought out. Since the investigation two cities tributary to Big Muddy have installed complete sewage treatment works, a third plant is under construction and two other cities have the necessary proceedings underway. It remains now to make some disposition of the more difficult mine wastes problem. Inasmuch as the destruction of fish life in the river seems to occur during periods of low flow, when some mine on Hurricane or Pond Creeks which has been idle for some time is suddenly thrown into operation, the suggestion occurs that the problem may not be so difficult as it first appears and that, with proper cooperation from mine officials, a rather inexpensive plan might be worked out for occasional neutralization of the mine water to prevent the recurrence of the periodical phenomenon that is so distressing to waterworks officials, sportsmen, and residents of the section.

PLANT ANATOMY AS A SCIENTIFIC AID TO APPLIED DESIGN

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The systematic study of plant morphology is based on three fundamental kinds of structural parts of any tree or other seed-bearing plants, namely, roots, stems and leaves. Each of these parts is composed of little structural units called cells, so small that in order to study them it is necessary to use a microscope that will magnify them many times their natural size.

Difference in function is the reason for difference in quality. These patterns differ greatly in different kinds of plants, but they are always the same in any one kind of plant. The different kinds of cells are grouped and arranged in such a way that they form very definite patterns. It is because of these beautiful forms found in the interior of plants that the author conceived the idea involved in scientific botanical design, a new application of the botanist's knowledge of plants.

In the same way in which plants have fundamental structural parts, pure design is also based on fundamental pleasing arrangements and composition, namely, Proportion, Balance, Sequence, Harmony, and Unity, elements which are at the base of all design, as in all normal plants. Some of the fundamental facts which are always true in nature have aided me in arrangement and composition and led me to establish a few rules for myself to follow. This gives me a logical reason for locating each unit in the proper place, with assurance that the design is scientically correct and complies with the accepted principles of good design.

In using natural patterns one should be consistent and competent to distinguish quality and to classify each structure according to it own value and purpose. It is reasonable to expect the cell structure to have individuality in the same degree in which we find individuality in the respective plants. They may be equal in quality but not alike, although each may have a decidedly uniform plan which is of logical significance. This has taught me that any careless disarrangement or misplacement of what I observed would be to destroy harmony. Each kind of plant specimen is separate and singular in style, beauty, and charm. Compare the

patterns derived from the maple with those of the pine and birch, independent and impossible to mingle with its neighbor. Each one is complementary to the other, yet so different, as they may be arranged or exhibited side by side and as the trees stand in the forest in all their grandeur and dignity.

It is of great significance where the patterns are obtained in nature, as this in a large degree must determine their quality and value, and govern the orderly arrangement of motives. Fundamental laws will guide the artist, whereby he may test his work, and an understanding of these laws can be gained only by a systematic training and a workable knowledge of his subject and material as a basis for the arrangement of motives discovered inside of plants. I have learned from botanical experimentation and independent research of internal plant morphology that definite and workable plans may be carried out according to the accepted rules of good design.

The question is often asked, "Where does the designer get his ideas, where does he find his patterns?" Old ideas, old motives, changed and worked over — that is his usual source. Why not try to discover something original, rather than conform to blind imitations? Why copy something from afar, only to present it so changed and mutilated that it has lost its original meaning? The replica of existing symbolic forms is not art, neither is the copy of a masterpiece a work of art, and yet the average designer resorts to copying and making over. This is his privilege to "pick up an idea anywhere" and conventionalize it, to reduce it to elements of simple line and form because he knows no other way. This can no longer be his excuse, for now we have discovered where to find patterns from the internal parts of plants.

Moreover, a representative knowledge of this subject in all its many forms and branches is possibly beyond the reach of any one individual. This does not mean that any student of this subject should be disheartened, for there shall be no single chapter of scientific botanical design that cannot be amended and extended for future work, but he must choose his special subject within the general field, and if he decides to throw in his lot with the experimentalists of the laboratory and studio, he may be assured that he could not join the experimenters at a more favorable time, inasmuch as the experimental method is pressing forward to the reaches of research, and it needs no gift of prophecy to foretell the future of plant anatomy as a scientific aid to applied art and design.

FLORAL TERATOLOGY IN LILIUM, DATURA, LATHYRUS, RIBES, HEMEROCALLIS, HEPATICA, AND MYOSOTIS

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Flowers, of the genera mentioned in the title, exhibiting peculiar and interesting abnormalities, were collected from plants found in or near Evanston, Illinois, in 1927. With the exception of *Hemerocallis,* only a single plant of each species was observed to produce abnormal flowers. However, many cases of the "double-flowered" *Hemerocallis* were observed, and a detailed study of fifteen such flowers is included in this report.

The abnormalities observed in the various flowers consist of deviation from the typical number of parts and malformation of structures. The causes of these monstrosities are not known, since the plants were not subjected to experimentation, though in some instances certain environmental conditions, such as temperature, suggest the possible stimuli.

Lilium longiflorum L.

Among the many Easter Lilies used in the exhibit of spring flowers at the Garfield Park Conservatory, Chicago, a single abnormal plant was noted. The stem was about four feet high and fasciated. It produced six flowers, two of which were normal in every respect, while the other four showed deviation from the typical number of parts and malformation of structures. Since the variation in each was individual, the flowers are described as A, B, C, and D. (Plates I and II.)

Flower A had seven perianth segments, of which five were typical (figure A). Two segments were smaller and otherwise abnormal. One of these was united with a normal segment along one margin and free on the other. The free margin was thickened, being rolled back at the midrib and having a flap-like lobe extending inward for nearly its entire length. The other abnormal segment, which was free as far as the receptacle, was inrolled, had several lobes of tissue, and along one margin for a short distance a pollen sac (figure 2). There were five stamens, four normal ones and one which had a slightly blade-shaped anther. The pistil

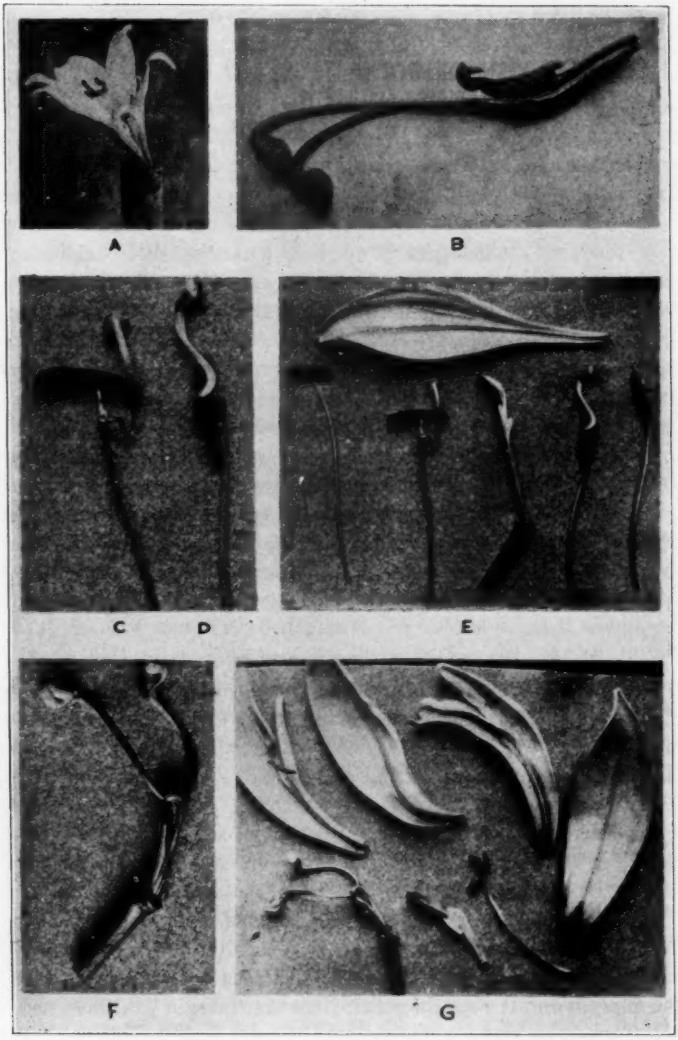

Plate I.

Photographs, showing the abnormal structures of the *Lilium longiflorum* flowers, some of which are shown in detailed drawings on Plate II.

FIG. A. Flower A before dissection.
FIG. B. The pistil of flower A.
FIGS. C-D. Stamens from flower D.
FIG. E. Structures of flower D.
FIG. F. The pistil of flower C.
FIG. G. Structures of flower C.

was quite unusual in bearing two styles with very large stigmas; and on the ovary one of the carpels was extended above the middle region into an elongated horn-shaped protuberance bearing pollen in a depression on its surface (Plate I, figure B, and Plate II, figure 3).

Flower B had six perianth segments, which were parted all of the way to the receptacle. One of them had a smaller petal-like lobe produced from its midrib and extending for more than half of its length. Otherwise the flower was normal.

Flower C had five perianth segments, two of which were of typical shape but free to the base. Two others were small, coalesced along two-thirds of their length, and very much thickened along the line of union. The fifth segment was lobed and had one inrolling margin. There were only two stamens and both were malformed. One (figure 4) had a short wide filament with a wing extension of petal-like tissue from which an anther protruded. Below this anther and along one side of the broadened filament another smaller atypical anther was formed. In the other stamen the filament was somewhat flattened, becoming broader at the base and producing pollen sacs which were split into two completely separate halves. The pistil was also malformed, being open near the apex and twisted to form a two-lobed apex exposing small ovules along its inner margin (figure 5). Styles arose from the two apical lobes and each produced an enlarged stigma which was split along one side. (Plate I, figures F and G.)

Flower D had six typically-shaped perianth segments that were slightly narrower than average, and free and distinct to the base. The pistil was lacking. Of the four stamens present, one was practically normal. The second had two white lobes on the filament, a small one arising a short distance below and a broader blade-like one just below the anther (figure 6). The third and fourth stamens produced stigmas on long style-like filaments branching from the connectives of large anthers (figures 7, 8). These stigmas were large and in general like those on the abnormal pistils in flowers A and C. (Plate I, figures C, D, and E.)

The cause of these monstrosities, on a plant which produced two normal flowers, is not known. The plants were grown in the propagating houses of the conservatory and may have been forced for early blooming. This was the only plant of several hundred examined that showed any apparent deformations.

There is little reference to monstrosities of *Lilium longiflorum* in the literature. Penzig (1894) states that Lynch (Gard. Chron.,

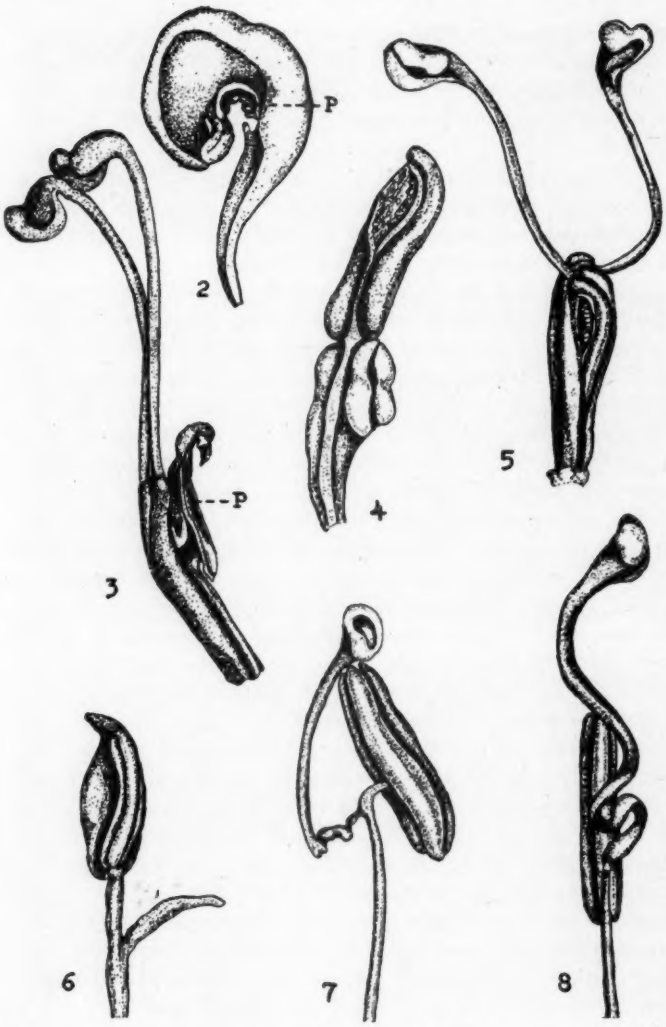

Plate II. Abnormalities of *Lilium longiflorum*.

Fig. 2. The single inrolled petal of flower A showing pollen on one margin P.

Fig. 3. The pistil from same flower, with two styles and pollen sac P extending from one carpel.

Figs. 4–5. Malformed structures of flower C.—4. Unusual stamen producing a second anther from the filament. 5. A pistil split and exposing ovules near lobed apex.

Figs. 6–8. Monstrous stamens from flower D.—6. Stamen with white petal-like outgrowths. 7, 8. Styles with stigmas arising from the connectives of anthers.

1886, II, p. 628) observed a flower with perianth segments parted to the base. Masters (1869) reports pistillody of the stamens in this species.

Datura fastuosa var. *alba,* Clarke

Late in the fall a single plant, which had appeared as a weed in a flower-bed on the campus of Northwestern University and was thought at first to be *Datura Stramonium* L., was noted to produce two blossoms of the hose-in-hose, or cornucopia type. The corollas were 5½ and 6 inches long, thus exceeding the maximum figure given for *Datura Stramonium.*

These flowers, designated here as *E* and *F,* had two corollas; the inner in each case was longer, more lobed, and much wider—and therefore folded within the outer tube. Upon dissection both of the flowers were found to have abnormal androecia.

Flower E had three narrow filaments and a single wide, branching one that was united with the inner corolla tube near the base (figure 9). Of the three narrower filaments, one had no anther and showed no evidence of ever having produced it, another formed practically a normal stamen, and the third possessed a thin, white, lobe-like outgrowth slightly below the anther. The fourth, or wide, filament was double, being fused along three-fourths of its length, then branching. On one branch there was a normal anther and below it on the filament was a small petal-like extension. The other branch produced two normally-shaped anthers at the apex of the filament. A sixth anther of an abnormal type was attached directly to the corolla tube (figure 9).

Flower F had five anthers, all of which were deformed. They were attached either on the lobes or at the sinuses of the inner corolla. On the tube, extending from the base to the anthers, were thickened ridges corresponding to filaments.

In both blossoms the pistils were of the usual type. The plant had other small buds, but these were dropped when the plant defoliated after being brought into the greenhouse to avoid frost. Although new leaves formed, there is no evidence of flower buds to date, so that it can not be determined whether all of the blossoms of the plant would be of an abnormal type.

The occurrence of a second or even a third corolla is reported to be fairly common among the Daturas, especially *Datura fastuosa.* Bailey (1914) states that this condition is likely to appear in practically any species. Wordsdell (1915) describes briefly a case cited by Goebel in which the androecium and

gynoecium were imperfectly formed in a flower having four corollas. According to Masters (1869) "some forms of duplicate or hose-in-hose corollas are apparently due, not so much to the for-

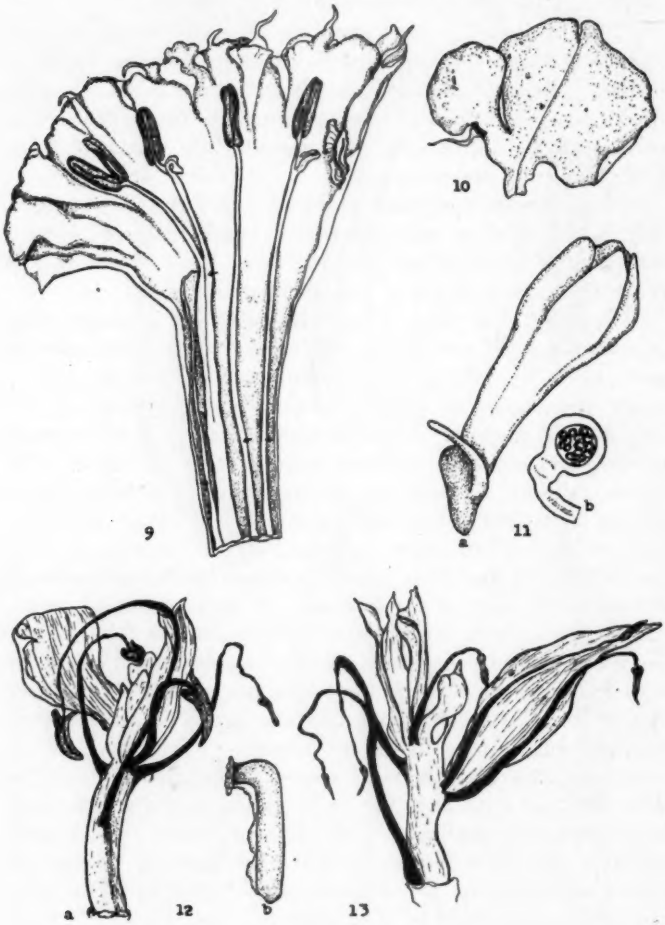

Plate III.

FIG. 9. The inner corolla of hose-in-hose *Datura* split open to show the abnormal stamens. The arrows mark the extent of the adherence of the filaments to the corolla tube.

FIG. 10. Standard of sweet pea flower showing pollen sac produced on lobe.

FIG. 11. Abnormal flower of *Ribes aureum*. a– habit sketch. b– c. s. of the ovary at the region of the outgrowth.

FIGS. 12, 13. Prolificated axes of *Hemerocallis* flowers bearing perianth segments and stamens. 12b. The central petaloid structure of the flower.

mation of a second corolla within the first, as to the presence of an inner series of petal-like stamens which, by their cohesion, form a second pseudo-corolla within the first. The staminal nature of this pseudo-corolla is inferred from the occasional presence of anthers on it." This seems very likely in this instance, as pollen sacs were found on the inner corolla in each case.

Lathyrus odoratus L.

Among some sweet peas obtained from a local florist a flower was noted in which the standard was enlarged and lobed. On the lobe a small pollen sac was produced from which extended a small elongated lobe of the same color as the petal (figure 10). Otherwise the flower was typical.

Ribes aureum Pursh.

On one of the numerous plants of *Ribes aureum* which grow on the campus of Northwestern University, a single blossom was noted to produce a peculiar horn-like outgrowth of the ovary (figure 11a). Upon examination this was found to be an inrolled petaloid structure of the same color as the sepals and about the same length as the ovary. It originated at about mid-point on the ovary, and a cross-section at this region showed it to be a continuation of the ovary wall (figure 11b). All other features of the flower were normal.

Hemerocallis fulva L.

Many cases of double flowers on *Hemerocallis fulva* were observed in gardens in Evanston, North Shore suburbs, and Chicago. Others were noted in South Dakota and Michigan, and along the roadside in Iowa they were found growing among plants which produced the single-type flowers. This condition was first noted among a row of many plants in the Botany Garden on the Evanston Campus. The first few flowers, opening about mid-July, were single and apparently otherwise normal. These plants, which had blossomed abundantly in previous years producing the single-type flowers, continued to bloom throughout the summer and to form only the double variety. However, they were not as prolific this season and many plants showed no indication of flowering. Those which did bloom were tagged and found to produce from several to numerous double flowers, a new one each day until the last bud had expanded.

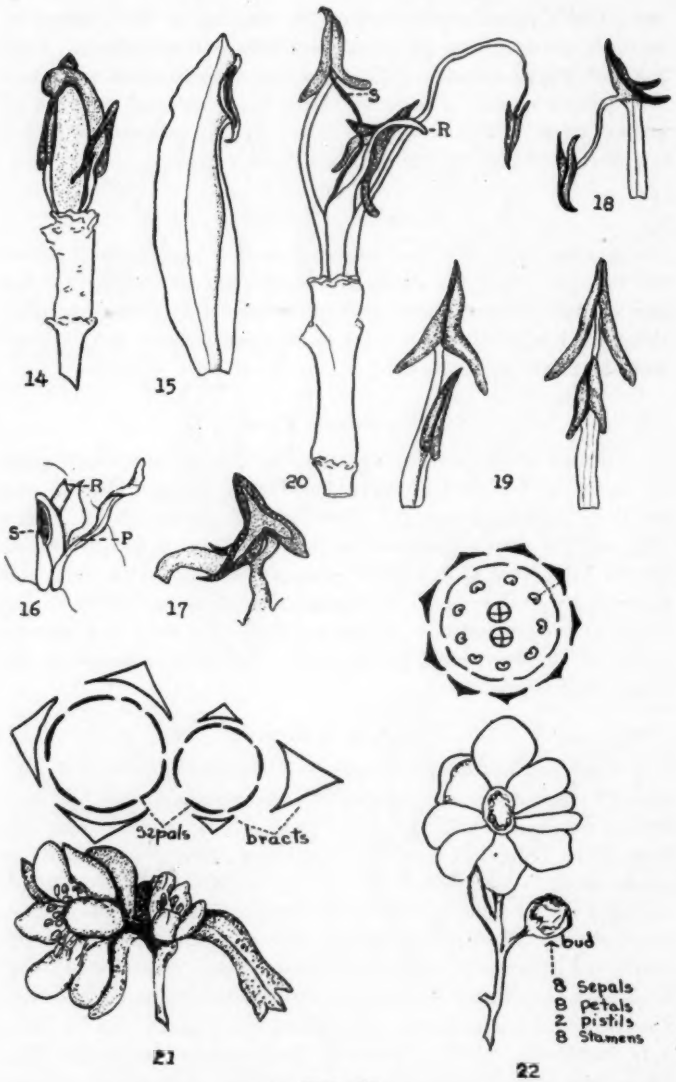

Plate IV.

FIGS. 14–20. Abnormal stamens of *Hemerocallis fulva*. *14*. From flower No. 5 showing inrolled terminal structure and two atypical anthers. *15*. Anther on a perianth segment from No. 4. *16*. Pollen sacs., attached to perianth segment, split open and showing a petal-like extension P from the vase of one sporangium: R-two extensions of perianth tissue. *17*. Anther from No. 3, with extension of the connective. *18*. Stamen from No. 14,

Pistils were lacking in every case. The perianth segments were all free and often had ragged margins, especially the inner ones.

Fifteen flowers were carefully studied and the results are shown in the accompanying tables.

As seen in Table II, there seems to be a fair correlation between the number of parts produced on the receptacle and the number on the elongated axis or stalk. Seven of the fifteen flowers had a total of 23 floral parts, whereas the others varied in having from 20 to 25. There seemed to be no general rule concerning the number of anthers, either on filaments or on perianth segments. The number on filaments, in the individual flowers, varied from 4 to 14, and those on the perianth segments from 1 to 7. The minimum number of anthers in any one flower was 9, which occurred in four cases, and the maximum number was 14. Six stamens on the receptacle, the normal number for this plant, were observed in only two cases. In Table II it will be noted that the number of abnormal perianth segments, which generally had anthers on them, added to the number of stamens on the receptacle, makes a total number of 6, in five cases, which suggests that petaloidy of stamens was probably the cause of the abnormal perianth segments.

Abnormality of stamens other than unusual position and lack of filaments, was frequently observed. Some of these peculiarities are shown in figures 14 to 20.

At the terminal of the prolificated axis there were usually found several small pale-orange segments which were often rolled inside one another (figures 12, 13, 14). Occasionally these petal-like structures were absent near the apex and stamens terminated the stalk (figure 20).

The peculiar formation in these flowers is probably similar to the condition which Penzig (1894) states was observed by Godron.

Grier (1918) reports six double flowers of *Hemerocallis fulva*, collected at Kirkwood, Missouri, in which the perianth was composed of distinct segments, but definitely twelve. Likewise, there

with second anther produced on a filament arising from connective tissue. *19.* Two views of same stamen, showing a second anther produced on the filament below the first. *20.* Central structure of No. 7, showing two abnormal stamens. R– connective of peculiar stamen which extends beyond the pollen sacs. S–a thin filament which extends from the connective of the anther under a lobe of another anther to the base of the latter's filament, firmly united at both ends.

FIG. 21. Habit sketch and floral diagram of an abnormal *Hepatica*.

FIG. 22. Habit sketch and floral diagram of an abnormal *Myosotis* flower.

TABLE I—NUMBER AND CHARACTER OF PARTS OF FLOWERS OF HEMEROCALLIS FULVA L.

Flower No.	On receptacle			On stalk			Character of the terminal structures
	Perianth segments without anthers	Perianth segments with anthers or otherwise abnormal	Normal stamens	Perianth segments	Normal stamens	Abnormal stamens	
1	7	2 half length, with thickened midrib.	4	6 light orange petal-like.	4	1, attached on abnormal petal. (figure 16).	Thickened incurved greenish envelope open along one side and with a loose ruffle of tissue on one margin, terminating in an orange colored disk. (figure 12b.)
2	7	2 as in A.	3	1 pale orange broad petal-like.	6		5 small pale orange segments (figure 13).
3	7		6		7	1, abnormal in shape and with a peculiar extension on one side (figure 17).	2 inrolled light orange colored petal-like structures.
4	7	2 as in A and with anthers (figure 15).	3	5 large (2 with anthers). 1 small with anther.	1 small		2 yellowish contorted small leaf-like structures with anthers.
5	6		5	6 (2 with anthers).	1	2, filaments short anthers atypically shaped.	2 segments, one pale orange, other green, infolded around a central immature anther (figure 14).

TABLE I—Continued.

Flower No.	On receptacle			On stalk			Character of the terminal structures
	Perianth segments without anthers	Perianth segments with anthers or otherwise abnormal	Normal stamens	Perianth segments	Normal stamens	Abnormal stamens	
6	6	2 as in D.	4	3	5		Elongated thickened central structure enclosed by inrolling of 2 small orange petal-like segments.
7	6	4 with anthers.	2	3 (2 with anthers).	3	2, forming central structure.	One stamen fairly normal in shape but with a long filament extending from connective to filament of another stamen where it was attached on other stamen. The connective was elongated into a horn-like protuberance and pollen sacs were atypical in shape. (figure 20).
8	9		3	2 small (with anthers).	4		Inrolled petal-like structures with three other segments closely inrolling (with anthers).
9	7		4	3	6		2 inrolling perianth segments.
10	7	2 with anthers.	3	2	4	2	3 central perianth segments (2 with anthers).

TABLE I—Concluded.

Flower No.	On receptacle			On stalk			Character of the terminal structures
	Perianth segments without anthers	Perianth segments with anthers or otherwise abnormal	Normal stamens	Perianth segments	Normal stamens	Abnormal stamens	
11	7	1 with anther.	5	6 (3 with anthers).		2	As in E.
12	7	1 with anther.	5	7 (3 with anthers. 1 abnormal and with anther).	1		2 inrolled pale orange perianth segments.
13	7		5	4 (1 with anther).	5	1	1 curved and inrolled small perianth segment.
14	7		4	3	4	2, producing a second anther from the connective in one case and filament in other (figures 18 and 19).	3 small yellowish segments (2 with anthers).
15	6		6	6 (2 with anthers).		1	Single inrolled perianth segment.

were twelve stamens. The styles were two and mostly aborted to a C-shaped or claw-shaped appendage, and the ovules were usually minute.

The presence of only single flowers in former years in the Evanston garden, and likewise in a garden in Glencoe, and the appearance this season of only the double variety (with the exception of the very few which bloomed first in the Evanston garden), raises the question whether these plants should be classified as *Hemerocallis fulva* var. *Kwanso,* Hort. It seems more likely that in this case the plants were not the horticultural variety called the double orange lily, but that the doubling and accompanying deformations which appeared in either cultivated or wild plants of *H. fulva* were caused by a stimulus or stimuli so far undetermined. Temperature may have been the causal factor, as a long cool spring was characteristic of all localities where this phenomenon was observed. During the summer of 1928 double flowers again appeared, on the plants in the Botany Garden, which showed the same type of abnormality. Such flowers, however, were not as abundant as the previous year.

TABLE II—SUMMARY OF NUMBER OF PARTS OF FLOWERS IN TABLE I.

Flower No.	Total structures			Stamens		Stamens and abnormal perianth segments on receptacle		
	On receptacle	On central axis	Total	On filaments	On perianth segments	Perianth segments *Anthers	Stamens	Total
1	13	12	25	8	1	2	4	6
2	12	12	24	9	0	2	3	5
3	13	10	23	14	0	0	6	6
4	12	9	21	4	7	2*	3	5
5	11	11	22	8	2	0	5	5
6	12	11	23	9	2	2*	4	6
7	12	8	20	7	6	4*	2	6
8	12	10	22	7	5	0	3	3
9	11	11	22	9	0	0	4	4
10	12	11	23	9	4	2*	3	5
11	13	10	23	7	4	1*	5	6
12	13	10	23	6	5	1*	5	6
13	12	11	23	11	1	0	5	5
14	11	12	23	10	2	0	4	4
15	12	8	20	7	2	0	6	6

Hepatica triloba Chaix.

Late in April a peculiar Hepatica was brought in from an Evanston garden. Only one such case was found in this garden and an extensive search for similar or otherwise abnormal blossoms among wild plants brought no results. The flower stalk in this instance bore two blossoms, one of average size and in its axis a much smaller one (figure 21). The larger of the two flowers had three involucral bracts of normal size and appearance, while the smaller flower had two bracts of proportionate size and a third which was about four times the length of the other two and leaf-like in appearance. The larger flower had six large sepals and one small sepal, while the six sepals of the smaller flower were approximately the same in size (figure 21). Stamens and carpels were many, as is typical for the species.

Myosotis scorpioides L.

Two abnormal flowers were found on a plant which was purchased at a local florists in January. This plant had undoubtably been forced. However, the method of forcing is not known, and even if it was the cause of these malformations it could not be considered general, since only this one flower stalk, among a great many examined at this and later times, showed abnormalities.

A flower and one bud exhibited deviation from the normal, chiefly in the number of floral parts. The flower (figure 22) had 9 sepals, 9 petals (2 of which were only one-half the average size), 9 stamens, and 2 pistils with 4 nutlets each. The bud had 8 sepals, 8 petals, 8 stamens, and 2 pistils. All other flowers and buds on this plant produced the typical number of parts and were otherwise normal.

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A PRELIMINARY STUDY OF THE CESTODES OF THE SPOONBILL
Polyodon spathula (Wal.)

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The material upon which this paper is based was collected at Money, Mississippi, where field studies were carried on from February until June and during the latter part of August and the first few days of September, 1927. The hosts were taken by commercial fisherman from the Tallachatchie River and adjoining lakes, and were dressed before shipment to New York and Chicago. Inasmuch as the number of spoonbills secured daily averaged 25 to 30 and often was as great as 100 or more, the material for examination was exceedingly plentiful and the chief limiting factor in the study was the number of individuals that could be accurately studied each day, not the number available for such examination. In all, 171 spoonbill were studied, ranging in size from 2 to 50 pounds. Of this number the head and gills only were studied in 30 specimens, and in the remaining 139 the intestine and viscera were examined.

In dressing the fish for market, the heads were removed and the body eviscerated. Thus it was possible to examine the entire intestinal tract of each specimen studied, and in some cases the entire fish was available for study. It was not an uncommon occurrence to observe both mature and larval cestodes on the dressing block, for so completely filled was the intestinal tract of some individuals that the worms crawled out from the esophagus or the posterior region of the spiral valve during the dressing process. This also happened often when an accidental cut was made in any other part of the alimentary canal.

For ease in examination the alimentary canal was divided into its 4 natural parts: the esophagus, stomach, pyloric ceca, and spiral valve. As soon as possible after the fish was dressed the canal was cut into these parts and each portion placed in a clean container. Beginning at the anterior division, each was then cut lengthwise and the large cestodes removed. Finally, each segment was placed in a clean fruit jar (1 quart size) and shaken vigorously

with a small amount of water, and the mixture was poured into a silk plankton net or sieve. By this method it was felt that a quantitative collection was secured from each of the divisions of the intestinal tract.

The results of a preliminary study of this collection warrant the conclusion that the spoonbill in this locality harbors 3 species of cestode parasites. This was not so evident until the study was well underway, however, for the general appearance of these three species is quite similar and the small larvae are practically indistinquishable. Careful study, and the occurrence of all 3 species in several adult hosts, made it possible to quickly distinguish the adults of each species. The data accumulated from subsequent collections and study indicate that in addition to morphological details these species differ among themselves in size, appearance in the living condition, region of host infection, seasonal distribution, and perhaps in life history. The details of this morphology are now being studied and will be presented in a later paper, but the important facts relative to their general morphology, together with their relative degree and incidence of infection, as well as other facts of value for rapid field determination, will be considered briefly at this time.

The most common of the 3 cestode species of the spoonbill is *Marsipometra hastata* (Linton). This species was originally described by Linton in 1898 but his description was quite incomplete, and the form was restudied and redescribed by Cooper in 1918. Linton described the color of the living species as follows: ".....at first lemon-yellow; after lying in water for a few minutes the body became colorless or faintly bluish translucent, while the heads remained yellowish." Cooper based his study on preserved material and added nothing to the description of this cestode in life. My own observations on living material are in entire accord with those of Linton. While the size of the specimens collected varied from 0.425 to 210 mm. in length, all had the characteristic yellowish color in life, and the scolex of the large forms remained so after lying in water for some time, although the proglottides of the large forms and the entire body of the larvae soon became colorless. The extreme activity of the large larvae and mature forms was a characteristic feature.

Cooper's description of the external appearance of the scolex and strobila is much more accurate than Linton's and may be noted in part, as follows:

"Medium-sized cestodes up to a length of 110 mm. with a maximum breadth of 3 mm. at the middle. Scolex with deep bothria and prominent posterior borders, 1.5 to 2.8 mm. in length, 0.5 to 1.8 mm. in width anteriorly and 1.3 to 2.0 mm. posteriorly. Sub-cylindrical neck, 0.8 to 1.5 mm. wide. First segments very short and wide, middle much broader than long and rectangular in outline, posterior ones quadrate to slightly longer than broad. Whole strobila much depressed."

Certain additional notes should be recorded concerning the appearance of this form in life. The anterior portion, particularly the scolex, shows marked powers of elongation. The scolex is thrust, both forward and laterally, with great rapidity, and at such times the length of this portion may be three times its normal length when at rest, with the width and thickness varying in proportion. During such activity in the anterior half of the cestode, the posterior angles of the segments are much more distinct than in the preserved specimens.

It is of interest to note that of the 139 spoonbills studied, only one was entirely free from this species of cestode. In all the others either larval or adult forms or both were found. The average number of cestodes of this species found per host was about 400, although a maximum number of over 5,000 (mostly larvae) was collected from a single host. The distribution of this species in the intestinal tract proved an additional point of interest. In 5% of the hosts *M.hastata* was found only in the spiral valve; in 42% in both the spiral valve and plyoric ceca; in 5% in the stomach, ceca, and valve; and in 11% in all 4 regions of the intestine. The greatest infection was usually in the pyloric ceca and spiral valve. Mature parasites were collected during the entire course of the field work from February until September, but the heaviest infection was found in the summer and fall months.

Experiments were conducted to determine the important steps in the life history of this species. Adults were found to extrude eggs immediately after being placed in artesian water or rain water, but did not respond well in this respect to Ringer's solution. Almost immediately after the eggs were extruded the oncospheres forced their way through the egg membrances and began swimming actively about. Feeding experiments with many different species of copepods, a very common article in the spoonbill diet

(Eddy and Simer, 1929), failed to indicate a probable intermediate host; for in no case were the eggs eaten by any of the copepods. The occurrence of small larvae in such large numbers in the intestinal tract is evidence that the intermediate host is ingested in great numbers, but conditions at the time these experiments were conducted were not conducive to successful experimental work. It was noted that adult tapeworms remained alive and active in artesian water for only 6 days, but in Ringer's solution they retained their activity for a period of 13 days. In the latter case, however, the chain of proglottides showed a tendency to fragment after the 4th or 5th day, and activity was then limited to the portion containing the scolex, while the proglottides in the other segments often assumed an extremely irregular form.

The second species of cestode encountered in this study has been designated *Marsipometra parva.*

MARSIPOMETRA PARVA spec. nov.

Specific diagnosis: Small cestodes up to a length of 150 mm. with a maximum breadth of 1.40 mm. Scolex a truncated cone, flattened dorsoventrally, and provided with a flattened knob-like anterior end. Maximum length of scolex 1.044 mm., maximum width at enlarged base, 1.74 mm. Bothria not visible in total preparations. Neck narrowed behind scolex, subcylindrical, 0.39 to 0.87 mm. wide. First segments only slightly wider than long, and at approximately the same stage of maturity as the posterior segments. Middle and posterior proglottides slightly longer than wide. Entire strobila depressed and constricted at union of proglottides.

Genital cloaca large, at the margin of the proglottis, slightly anterior to the middle, and irregularly alternating. Vagina opens at about the same level as the cirrus. Testes ellipsoidal, 60 to 80 μ in diameter, 35 to 60 in number, and distributed throughout the cortex with the exception of the region of the uterus sac. Vas deferens a circular mass of coils dorsal to the uterine pore, 0.080 mm. in diameter. Cirrus sac elongate, 0.35 mm. long by 0.060 mm. in diameter.

Vagina about 0.020 mm. in diameter. The ovary is reniform, tubulolobular, 0.261 mm. wide, and 0.174 mm. long. The vitelline follicles are irregular in shape, and distributed throughout the proglottis with the exception of the central area. The shell gland is anterior to the ovary, near the mid-line. Uterine sac small, circular, and greatly enlarged in gravid proglottides by the formation of 8 to 12 radial pounches, which reach almost to the lateral margins of the proglottis. Uterine pore in the mid-line, slightly anterior to the level of the genital cloaca. Eggs 28 by 20 μ.

The characters of most importance in the recognition of this species in the living condition are its peculiar shaped scolex, white color, small size, chain of bead like proglottides, and the absence of almost all activity. The elongations of the living adult are slow and of short duration and are limited to the anterior one third of the strobila. The poorly developed condition of the suckers is indicated by the fact that in no case, either in larvae or adults, was this species found attached to the tissue of the host. The union between the proglottides in this species appears to be an extremely secure one; for in no case were separate proglottides found except where an entire chain had broken loose from the scolex at the constricted neck region.

M. parva was not found as commonly or in such large numbers as was *M. hastata*. It was discovered in only 52 of the 139 examinations, the first larvae being secured February 15 and the first mature forms February 28. The last specimens collected during this study were secured April 23. This would indicate that the period of infection by this species is quite restricted in comparison with the other species considered. The average number of cestodes of this species present in each infected host was 26, but this includes both larval and mature forms. In 81% of the infected hosts, infection was limited to the region of the spiral valve, and in 17% infection occurred in both the pyloric ceca and spiral valve. In only one host were parasites taken from each of the three posterior regions of the intestinal tract.

Attempts were made to discover facts that would shed light on the life history of this species, but these did not meet with success. The eggs were extruded in great numbers, but no outer membrances could be seen, nor was it possible to study the morphological details of the eggs. No movement was observed, and none of the various species of copepods ingested the cestode eggs. The extremely limited period during which this species was collected from the spoonbill would seem to indicate that a seasonal distribution of the intermediate host is likely, but no proof of this supposition can yet be advanced.

The third species of cestode taken from the spoonbill has been named *Marsipometra confusa* because of the similarity of the living specimens of this species to *M. hastata*.

MARSIPOMETRA CONFUSA spec. nov.

Specific diagnosis: Medium-sized cestodes up to a length of 120 mm. and a maximum breadth of 2.088 mm. at the middle. The scolex in life is spool shaped with prominent suckers, the base slightly broader than the anterior part, and the entire organ flattened dorsoventrally. In preserved material the outline of the scolex is conical with a blunt anterior end, and no suckers are visible. Maximum measurements of the scolex are 1.044 mm. long and 0.87 mm. in breadth. The posterior region of the scolex narrows to join the somewhat constricted and subcylindrical neck, about 0.696 mm. in width. The first segments are very short and wide, the middle ones about as broad as long, and the posterior ones somewhat longer than broad. The entire strobila is much depressed and increases gradually to a maximum width near its center.

Genital cloaca near the middle of the margin of the proglottis, alternating irregularly. Vagina opening at about the level of the cirrus. Testes ellipsoidal, 60 to 100 μ in diameter from 180 to 260 in number, arranged in a single layer in the medulla, lacking in the region of the uterine sac. and at lateral margins. Cirrus sac short and cylindrical, 0.360 mm. long and 0.080 mm. in diameter. Cirrus 0.240 by 0.020 mm. Vagina 0.020 mm. in diameter. Ovary reniform and tubulolobular, 0.609 mm. wide by 0.267 mm. long. Vitelline follicles irregular in shape and size, in a layer around the proglottis. Shell gland anterior to the ovary, near the mid-line, about 0.174 mm. in diameter. Uterus sac in immature proglottides longitudinal in the mid-line, extending from the shell gland to near the anterior border of the proglottis, diameter 0.087 to 0.174 mm. In mature forms 5 to 8 lateral pouches on either side, extending to the region of the lateral nerve cord. Uterine pore at the posterior end of the uterine sac, anterior to the ovary. Eggs spherical, about 0.070 mm. in diameter.

The characters of special value in the field determination of this species are the shape of the scolex in both the active and inactive forms, the deeply serrated lateral boundaries in the active specimens, the short period of activity, and the ease with which segmentation of the strobila occurs.

Of the 139 spoonbills examined, 51 contained *M. confusa*. The first specimens were collected March 14, and infection continued as long as these studies were under way. The average number found in each infected host was 24. In 70% of the hosts infection was limited to the pyloric ceca, and in 11% infection occurred in both the stomach and ceca. In one host all four regions of the intestine contained this species. Experiments conducted in an attempt to elucidate the life history of *M. confusa* were generally unsuccessful as far as the determination of the intermediate host was con-

cerned, but eggs were easily obtained, were seen to hatch, and the 6-hooked, ciliated oncosphere was studied.

SUMMARY

Quantitative collections of the intestinal contents of 139 spoonbill indicate the occurrence of three species of pseudophyllidean cestodes in this host. The most frequent species was *Marsipometra hastata* (Linton, 1898), found in all regions of the intestine and in all but one examination. *Marsipometra parva* spec. nov. was found in 52 of the hosts and was limited in most cases to the region of the spiral valve. *Marsipometra confusa* spec. nov. was found in 51 of the hosts and was collected in a majority of cases from only the pyloric ceca, although it was also found in the stomach and spiral valve in a small percentage of the hosts.

The three species differ in shape and size of the scolex, the appearance of the strobila, and the shape of the uterine sac. There are also many minor points of difference in their anatomy. From the data at hand they appear to differ in seasonal infection and in degree of infection.

Attempts to elucidate the life history of these species were unsuccessful. In each, eggs were secured in quantity, but only in *M. hastata* and *M. confusa* were the oncospheres observed. No evidence was secured to indicate what forms serve as the intermediate hosts of these cestode species.

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THE HARDINESS OF SOYBEAN SEED AS RELATED TO SEED COLOR

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The soybean (*Soja max*) is one of the oldest agricultural crops grown. It originated in Asia, and for centuries it has been one of the main agricultural crops in Manchuria, Korea, China, and Japan. In these countries it is used for human food, being considered too valuable to feed to livestock. There are more than 800 varieties, the seeds of which vary in size, shape, and color.

This crop was introduced into the United States in 1804, but it was almost a century before it was given much attention by experiment stations and farmers. Since the beginning of the present century, however, the increase in interest has been very marked.

The investigations reported in this brief paper were undertaken with a view to learning whether there are any differences in the characters of soybean seed, other than the visible ones, which are peculiar to the different varieties. The first simple test consisted in weighing into small wire baskets 200 grams of each of 13 common, representative varieties and exposing them to the changing humidity of the atmosphere but protecting them from rain and snow. These were weighed at frequent intervals during a period of 120 days in order to note the effect of humidity upon the hygroscopic moisture of the soybeans. Table I, summarizing these tests, shows, in general, that the yellow varieties were most sensitive to varying conditions of the atmosphere, the black varieties were least sensitive, while the brown varieties occupied an intermediate position in this respect. The Pekin was an exception, behaving much like the yellow varieties.

EFFECT OF TEMPERATURE AND AN EXCESS OF WATER UPON VIABILITY

As a further study of character differences 8 varieties, namely, Manchu, Midwest, Dunfield, Illinois 13-19, Virginia, Ebony, Wilson, and Peking were submerged in water with thermostats to maintain the temperature at 10°, 15°, 20°, and 30° C. At intervals of 24 hours samples were taken from each for germination. Table II summarizes the results as at the end of 35 days.

TABLE I—TOTAL VARIATION OF HYGROSCOPIC MOISTURE IN SOYBEANS EXPOSED TO VARYING ATMOSPHERIC HUMIDITY, GIVEN IN PERCENTAGE OF ORIGINAL WEIGHT.

Variety	Color	Variation
Manchu	Yellow	9.20%
Haberlandt	Yellow	6.55%
A K	Yellow	6.62%
Madwest	Yellow	7.56%
Dunfield	Yellow	8.44%
Elton	Yellow	8.42%
Ito San	Yellow	7.28%
Virginia	Brown	6.96%
Illinois 13-19	Brown	6.26%
Ebony	Black	5.82%
Wilson	Black	4.92%
Wisconsin Black	Black	4.22%
Peking	Black	7.22%

TABLE II—NUMBER OF DAYS DURING WHICH EIGHT VARIETIES OF SOYBEANS SUBMERGED IN WATER AND KEPT AT DIFFERENT TEMPERATURES CONTINUED TO SHOW VIABILITY.

Variety	Temperature				Color
	10°	15°	20°	30°	
Manchu	10	9	3	3	Yellow
Dunfield	12	5	5	1	Yellow
Midwest	12	7	3	3	Yellow
Peking	35	33	30	15	Black
Ebony	30	30	17	3	Black
Wilson	35	35	35	15	Black
Virginia	35	35	35	30	Brown
Illinois 13-19	35	35	34	7	Brown

The rapid decline in viability of the yellow-seeded varieties was very noticeable. In a short time the seed-coats slipped off and putrefaction took place. No impermeable seed-coats were apparent. The black-coated beans declined much less rapidly. They swelled and the coloring matter was dissolved out by the water, but no disintegration took place as in the yellow varieties. There was a small percentage of impermeable seed-coats. The same observations apply to the brown beans.

The higher temperatures had a distinctly more deleterious effect upon viability than did the lower. This was marked in the yellow and to a less extent in the black and brown varieties.

FIELD TESTS

A. On November 24, 500 soybeans of each of the 13 varieties were sown on each of two plats 8 by 16 feet in size. On one of these wheat was drilled after the beans had been sown. On the other the beans were left uncovered through the winter and oats were sown on April 2 the following spring. Counts were made of the plants that came up on these two plats.

B. On November 29, 100 beans of each variety were planted in 16-foot rows at depths of 1, 2, 3, and 4 inches, respectively. In the spring counts were made of all the plants that came up in these rows.

C. On the same date 100 beans of each variety were buried 6 inches deep in a manner permitting their recovery and identification the next spring. On April 11 these were uncovered and counts made of the number that had sprouted. After counting, the beans were again covered with soil, but later investigation showed that no more had germinated.

The results of this field work are contained in Table III.

TABLE III—NUMBER OF PLANTS EMERGING IN THE SPRING FROM SEED PLANTED IN THE FALL.

Variety	Number of plants emerging in the spring						Number germinated
	500 beans sown in fall with wheat	500 beans sown in fall; oats in spring	100 beans planted—depth				100 beans covered 6 inches in fall
			1″	2″	3″	4″	
Yellow Varieties—							
Elton	0	0	0	0	0	0	0
Dunfield	0	0	0	0	0	0	0
A K	0	0	0	0	0	1	0
Manchu	0	0	0	0	1	0	0
Midwest	0	1	0	0	2	0	1
Ito San	0	3	0	0	0	0	2
Haberlandt	3	2	0	0	0	0	1
Brown Varieties—							
Illinois 13-19	11	5	3	5	5	10	15
Virginia	1	1	0	1	0	4	6
Black Varieties—							
Ebony	2	5	10	13	17	17	10
Wisconsin Black	0	1	1	2	3	2	15
Peking	24	9	7	13	22	23	10
Wilson	20	17	18	16	18	10	33

In all of these tests the brown and the black varieties withstood the unfavorable conditions much better and produced more plants than did the yellow beans.

D. In the fall, soybeans of the Manchu, the Ebony, the Wilson, and the Virginia varieties were left standing in the field in order to observe the effect of the winter upon their viability under these conditions. The results of germination tests made at two different dates in the winter are shown in Table IV.

TABLE IV—GERMINATION OF FOUR VARIETIES OF SOYBEANS LEFT IN THE FIELD DURING THE WINTER.

Variety	Color	Percentage of germination	
		December 20	February 26
Manchu	Yellow	37	3
Virginia	Brown	98	60
Ebony	Black	97	35
Wilson	Black	97	56

Table IV again brings out the greater hardiness of the black and the brown varieties. The differences in ability to withstand adverse conditions cannot be explained on the ground of impermeable seed-coats. The reasons for the differences would furnish an interesting subject for further investigation.

WITCHES' BROOMS OF THE CHICAGO AREA

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My interest in those curious plant deformations called galls led to a study of witches' brooms. The purpose of this paper is merely to list those which have come under my observation in the Chicago area, principally in the vicinity of Elgin, with the hope that it may interest others and lead to further study of them.

The origin of the witches' brooms described here is unknown to me excepting that of the hackberry (*Celtia occidentalis* L.) which is caused by the mite (*Eriophyes* sp.). This was the first to attract my attention, and I found it to be very abundant, as shown in Fig. 1. They vary in size, reaching a maximum of about 12 inches in diameter. The tree shown in the illustration is growing near the Desplaines River at River Grove, and it was found April 23, 1922.

Fig. 2 shows a broom on the willow (*Salix longefolia* Muhl.). This was found in large numbers in a swamp near Spaulding, Illinois, March 17, 1929. The average diameter was about 12 inches.

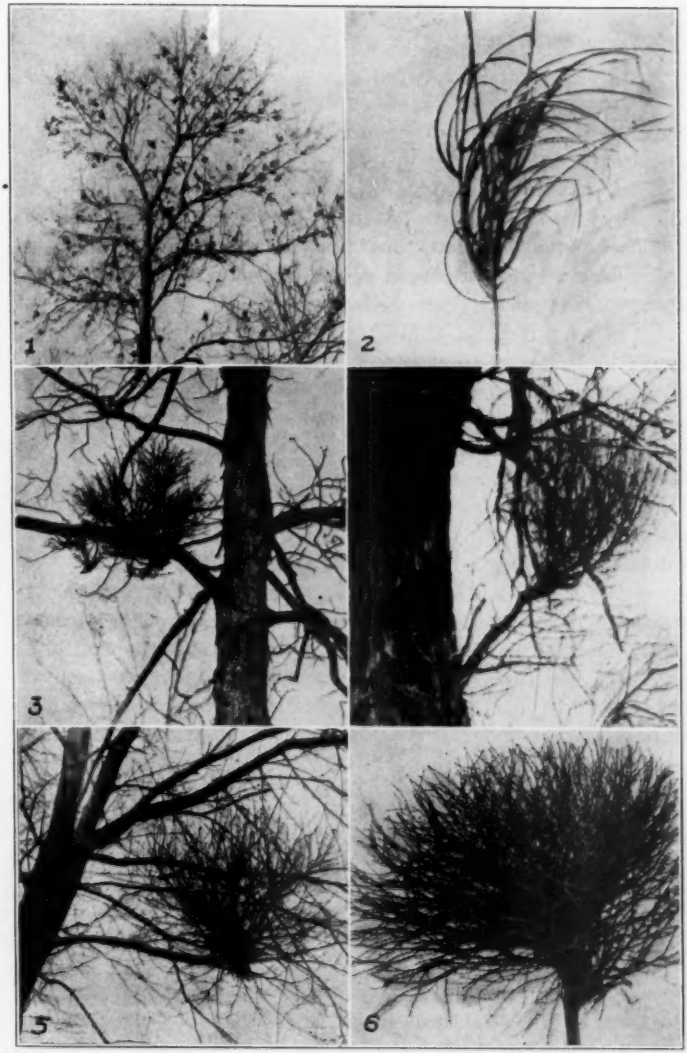
I have found witches' brooms on hickories (*Carya alba* Nutt.) in three different localities. The illustration in Fig. 3 represents one of three brooms found on the same tree near South Elgin, Illinois, in 1924. Two others were found in Lord's Park (Elgin) and several more about five miles west of Elgin. Their average diameter was about 3 feet.

Fig. 4 shows a broom on the willow (*Salix nigra* Marsh.) found near Elmwood Cemetery, River Grove, Illinois, May 5, 1923. Its diameter was about 4 feet. My first specimen was found near Dundee, Illinois, April 23, 1923, and its diameter was about 3 feet.

The broom on box elder (*Acer negundo* L.) illustrated in Fig. 5 was found at Itasca, Illinois, Dec. 2, 1923. Diameter 5 feet. A smaller broom was found in Elgin in 1928.

I have found but a single broom on the larch, and this on *Larix decidua* Mill., which is represented in Fig. 6. This broom was found near Udina, Illinois, on State Route No. 5, in 1922.

I have been informed that brooms have been seen on the pine (*Pinus strobus* L.) at the "Dunes" in Indiana.



Witches' Brooms.

CAPILLARIASIS OF CHICKENS

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University of Illinois, Urbana.

It is the purpose of this paper to report the occurrence of Capillariasis in three widely separate Illinois farm flocks. In a previous note this parasite was reported in two flocks[1]. The pathological changes encountered in the ingluvium and esophagus in affected fowls from two flocks resemble the gross lesions of *Capillaria annulata* infestations. In one fowl from a third infested flock the gross lesions at autopsy suggested the possibility of another species of Capillaria being present.

Cram [2, 3] reported finding of *Capillaria annulata* in affected grouse in Michigan, in chickens from Georgia, Mississippi, and Louisiana, and from turkeys in Maryland. Jungherr [4] reported the same parasite in turkeys in Montana. Hung [5] described the histopathology of *Capillaria annulata* infestation as observed by the writers, which resembles lesions in fowls described as cases 1 and 2 coming to our attention. It is possible that the gross pathology in intestinal Capillariasis may ultimately aid the autopsiest in distinguishing different species of this parasite.

Cases 1 and 2. In specimens from two of the farm flocks mentioned, a nematode parasite was found in several of the affected birds from both groups. The condition appeared in the fall and had, up to the time of diagnosis, assumed an insidious course, so far as could be learned not more than one or two birds becoming affected each week. The symptoms observed in both flocks that harbored Capillarids consisted of lack of vigor, emaciation, ruffled feathers, droopiness, lameness, progressive torticollis, finally extreme helplessness and death. Affected fowls die in ten days to five weeks after displaying symptoms. The late hatches were observed to be the most often affected. Birds weighing from 2½ to 3 pounds were first attacked. The gross pathology in affected fowls from two flocks was confined to the lower portion of the

[1] Graham, R., Thorp, F., and Hectorne, R.—Capillaria Infestation in Chickens. Jour. Amer. Vet. Med. Ass'n., Vol. LXXIV, n. s., Vol. 27, pp. 1060–1063, June, 1929.
[2] Cram, E. B.—A Parasitic Disease of the Esophagus of Turkeys. North American Veterinarian, Vol. 7, No. 10, pages 46-48, October, 1926.
[3] *Ibid*—Nematodes of Pathological Significance Found in Some Economically Important Birds in North America. U. S. D. A. Tech. Bull. No. 49, pages 1 and 2, 1928.
[4] Jungherr, E.—Two interesting poultry diseases. Jour. Amer. Vet. Med. Ass'n. Vol. LXXI, n. s., Vol. 24, No. 5, pages 636-640, August, 1927.
[5] Hung, S. Lü—Pathologic lesions caused by Capillaria annulata. The North American Veterinarian. Vol. 7, No. 10, pages 49 and 50, October, 1926.

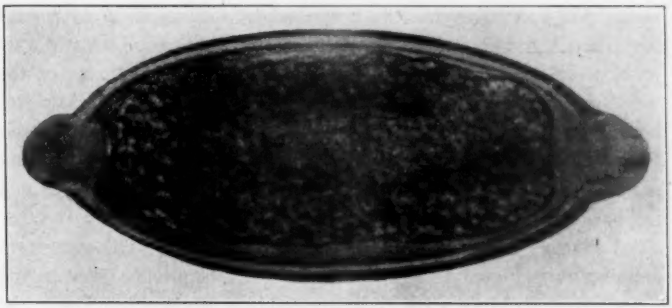

FIG. 1. *Egg of Capillaria sp.* (Many times enlarged.)

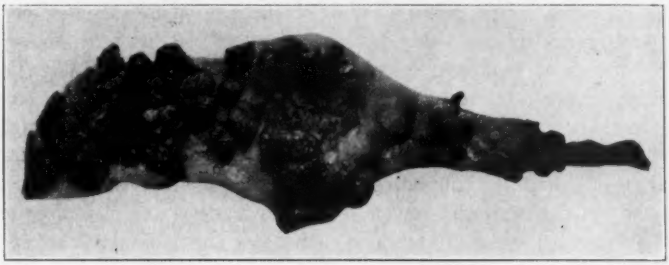

FIG. 2. Follicular diphtheritic enteritis.

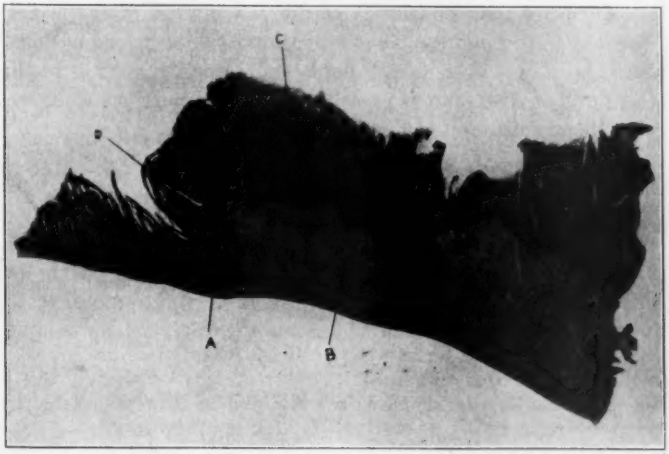

FIG. 3. Histopathology of follicular enteritic lesion: (a) the line of demarcation between circular muscle and the regenerative fibrosis; (b) regenerative fibrosis; (c) necrosis of intestinal epithelium; (d) junction of regenerating fibrosis and diphtheritic membrane.

esophagus and ingluvium as described in *Capillaria annulata* infestations. A very putrid odor was noted when these organs were opened. An ingluvitis was detected. The lymph follicles of the wall of the ingluvium were increased in size and a slightly adherent diffuse fibrinous pseudomembrane extended over the surface. Small circumscribed patches of the mucosa were necrotic and easily displaced on pressure. Scrapings from the inflamed ingluvium revealed a few mature Capillarids embedded in the diseased mucous membrane together with many eggs. The eggs were doubled, operculated and easily recognized. Capillaria eggs in the three infested flocks were indistinguishable upon microscopic examination. (Fig. 1).

Case 3. In a group of adult chickens purchased from a local poultry dealer, one sickly fowl was noticed. This bird showed symptoms of weakness, anemia, and emaciation for several days before death. At autopsy the intestine just anterior to the ceca showed a marked dilatation. The gross pathology revealed a follicular diphtheritic enteritis of the wall of the dilated intestine (Fig. 2), with the contents giving off a foul odor. Histopathologic study of the intestinal lesions revealed a necrosis and sloughing of the intestinal epithelium. The submucosa and muscularis showed infiltrating areas of fibrin filaments and a chronic fibrosis (Fig. 3). The disintegration and fibrous infiltration of the circular muscle fibres explain the intestinal dilatation. Scrapings of the necrotic membrane upon microscopic examination revealed masses of double operculated eggs as in cases 1 and 2, and a small number of mature Capillarids. The mature parasites, though minute, could be seen with the unaided eye.

Summary. The symptoms and lesions in fowls from three different Illinois flocks, insofar as could be determined, were traceable to the presence of the nematode Capillaria. The possibility of two separate species of this parasite in cases 1, 2, and 3 is recognized.[6] These parasites impair the functions of the ingluvium and intestine. The gross lesions in one specimen were confined to the intestine, while the ingluvia and esophagus of several fowls examined from two other flocks were involved. Capillarids are probably more prevalent than supposed. To our present knowledge, this is the first time Capillarids have been reported in Illinois farm flocks.

[6] Doctor H. B. Ward, Professor of Zoology, University of Illinois, identified the genus as Capillaria in case 3. Since the above report was prepared Doctor Maurice C. Hall, Chief of the Zoology Division, Washington, D. C., advised that Miss Cram regarded the species referred to in case 3 as *Capillaria meleagris-gallapavo.*

SKELETAL ADJUSTMENTS IN A THREE-LEGGED CHICKEN*

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The specimen described in this paper was a full-grown Rhode Island Red cockerel offered for sale in a Chicago market. Except for the duplication of the leg on the right side of the body, it was a perfectly normal bird, in good condition. The superfluous leg was flexed, extended posteriorly, and evidently caused no inconvenience.

The duplication was unilateral; that is, the right leg with its pelvis was completely duplicated but there was nothing abnormal on the left side of the body. The right pelvis was somewhat irregular in shape and size, being 12 mm. shorter than the normal left pelvis and having the posterior region of the ischium shortened about 5 mm. The anterior pelvis had separated from the sacrum at the posterior end to make room for the secondary structure, and this made necessary a slight curve in the sacral vertebrae, together with other minor changes and shifts. This region of the sacrum became asymmetrical, with an additional rib on the side of the duplication and with an additional process connecting with the pelvis. All the processes of the sacrum were lengthened on the right side.

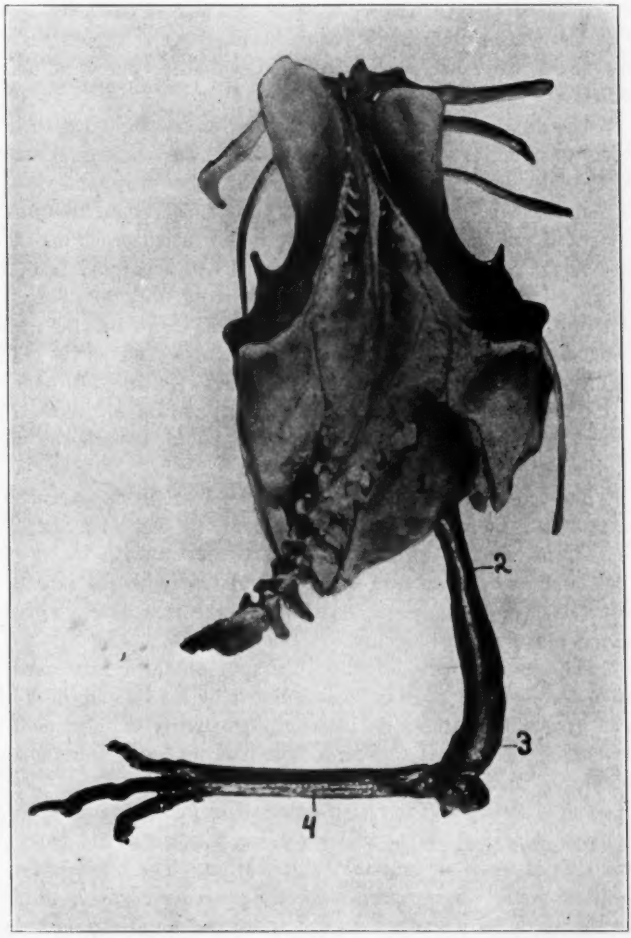
The accessory pelvis is somewhat abnormal in appearance because of the shortening of the ilium and the lack of a pectineal process and a pubis to allow better articulation with the normal pelvis and with the sacrum. The articulation with the sacrum is by means of one large sacral vertebra, but the articulation with the caudals makes it fairly secure.

The acetabulum is large, with a spur on the ventral rim, to which the accessory femur is articulated by a cup-shaped cavity. Such articulation allows only a slight possibility of movement in the femur. The usual foramina, both the obturator and the ilio-ischial, are lacking.

The accessory leg is rather interesting in its anatomy, being a mirror image of the normal right leg with all of its parts reversed, as is usual in unilateral duplication. The musculature is slight, as would be expected, since the movement was so limited. The femur lacks a trochanter and is altogether abnormal in ap-

* Contribution from the Zoological Laboratory of the University of Illinois, No. 357.

pearance, having a cup-shaped cavity instead of an articulating head. The tibiotarsus is very much shortened, being only about 15 mm. long, and is ankylosed to the femur. The tarso-metatarsus is also shortened, and the three bones that make up this segment, though joined, show their origin as distinct bones very clearly. The toes are abnormal in that the first is lacking and the fourth lacks one phalanx.



Dorsal view of the synsacrum, pelvis, and accessory leg of a three-legged chicken: (1) accessory pelvis, (2) femur, (3) tibiotarsus, (4) tarsometatarsus.

HOW BROKEN BONES ARE REPAIRED IN NATURE*

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University of Illinois, Urbana.

The tragedy of a broken bone in wild life is generally buried in the stomach of some predatory animal, so that only scant evidence of injury may be obtained from observing animals in their native habitats. But a study of any large series of skeletons will show examples of repaired fractures—evidence that many accidents occur in nature and that some animals recover from injuries severe enough to break bones.

Many breaks heal entirely, as is indicated by the small size of the callouses present; but sometimes there result various mechanical defects which interfere with movement. Fractures of skulls, vertebrae, and ribs usually heal with less mechanical disadvantage than fractures of limbs; for the latter are likely to result in shortened and stiffened members, because of the slipping of the broken ends and the pulling of the muscles. Such limbs have large bone callouses, and the repair work is poor in general, so that the segments are immovable. It is true that if only one of the paired bones of the leg is broken, it generally mends very well, since it is held in place by the sound bone, but a callous may form that will make the segment unable to continue its usual pronation and supination.

HOW FRACTURES OCCUR

Fractures occur in many ways, most of them through accidents during the normal activities of the animal, others in combat during the breeding season, and some by gunshot wounds. Arboreal animals, for example, suffer from falls that result in broken legs and ribs and injured spines. They make mistakes in judging distances and in gauging the strength of limbs on which they jump, and they are often careless. Climbing primates have frequent falls, for their skeletons show many instances of healed fractures, usually with complete recovery. Running animals frequently break legs by stepping in holes and by miscalculating jumps. Mountain animals, though very skilled in climbing and running, occasionally fall, and their skeletons are found at the foot

* Contribution from the Zoological Laboratory of the University of Illinois, No. 358.

of cliffs. The light bones of running animals in general are long and fragile and not able to withstand any severe strain. During the rutting season with its individual challenges for supremacy, many serious and even fatal injuries occur in these groups. Again, burrowing animals in dry regions suffer broken legs and backs when rocks slide in the burrows. Birds meet with serious injuries from flying into trees, wires, and other obstacles. They seldom recover from a fractured humerus, but a fracture of the radius or ulna may mend so that the wing is again serviceable. The latter is particularily true of water birds that are able to get food with a minimum of exposure during the time necessary for the wing to mend. Broken legs may not be very serious to flying birds, but they are usually fatal to ground birds, which cannot escape from their enemies. When a flock of ducks mistake a wet pavement for a stream, many of them suffer fractures of the clavicle and sternum and are made helpless. Some reptiles fight among themselves, and some are especially subject to injury from animals used for food. The smaller rodents, such as the gopher, can make a snake pay a dear price for his meal, because they inflict bites that result in ankylosed vertebrae, or cause the death of the snake. Amphibians not only suffer injuries from the bites of turtles, birds, and carnivores, but they are also crushed under the feet of larger animals at ponds and other drinking places.

SPECIMENS

Part of the material described in this paper as evidence of healed fractures was picked up in the field, and the rest was found in the course of preparing skeletons. In every case there was a recovery from the injury, though in some cases the broken bones were not repaired as well as in others.

VERTEBRAE OF A URODELE

(Plioambystoma kansensis)

An injury to the lumbar vertebrae in this small amphibian from the lower Pliocene was repaired fairly well. All of the parts are smooth. The three vertebrae are coalesced in such a manner that the posterior one is at an angle of 40°, and the middle one is so badly crushed that the centrum is completely lost. The spinal cord was not injured past recovery, for the new neural tube is smooth and of sufficient size to function in the repaired vertebrae. The posterior limbs and the pelvis must have been at an angle and twisted so that the animal would have to develop a peculiar bend in the body, in order to

walk and to have the hind limb touch the ground in a normal manner. The numbers 1, 2, 3 on the illustration indicate the neural spines of the three coalesced vertebrae.

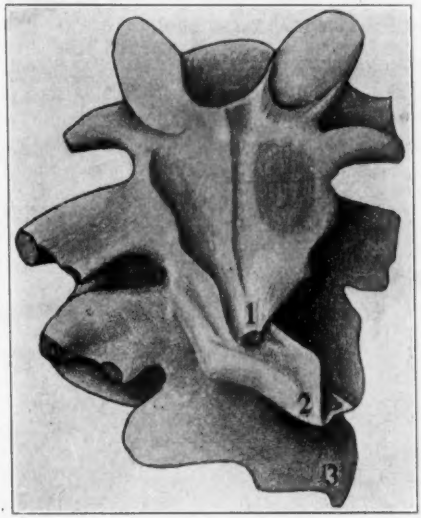

FIG. 1. Three coalesced vertebrae of a Pliocene urodele.

VERTEBRAE OF A PYTHON

The skeleton of an old python, 16 feet long, that had been carried with a circus, showed many evidences of combat. Several series of vertebrae were ankylosed, one section being 16 inches long, another 12, and another 7. The vertebrae appeared to have been crushed in the jaws of some large animal, possibly a carnivore, that the snake had been unfortunate enough to encounter. The injury was very severe, for there were large bone callouses remaining and the vertebrae in these sections were firmly ankylosed. Thus disabled, the python must have had a very peculiar locomotion. A number of ribs had been broken at the same time, and they also had been repaired in a fairly efficient manner.

ILIUM AND FEMUR OF A FROG

(Rana catesbiana)

In this specimen there is a severe fracture of the ilium, with the typical repair of a long bone. The pull of the sacral muscles has drawn the broken ends apart, so that there is a large callous and a consequent shortening, with the broken ends approximately ½ inch apart but connected by new bone tissue.

On the same specimen there is a fracture of the femur rather close to the hip joint. It has mended with a shortening, since the

broken ends have slipped past one another due to the pull of the muscles. There is a large callous present that must have interfered with normal movement of the muscles and the leg. From the condition of the bone, it is evidently an old fracture with a complete recovery, but with serious mechanical disability.

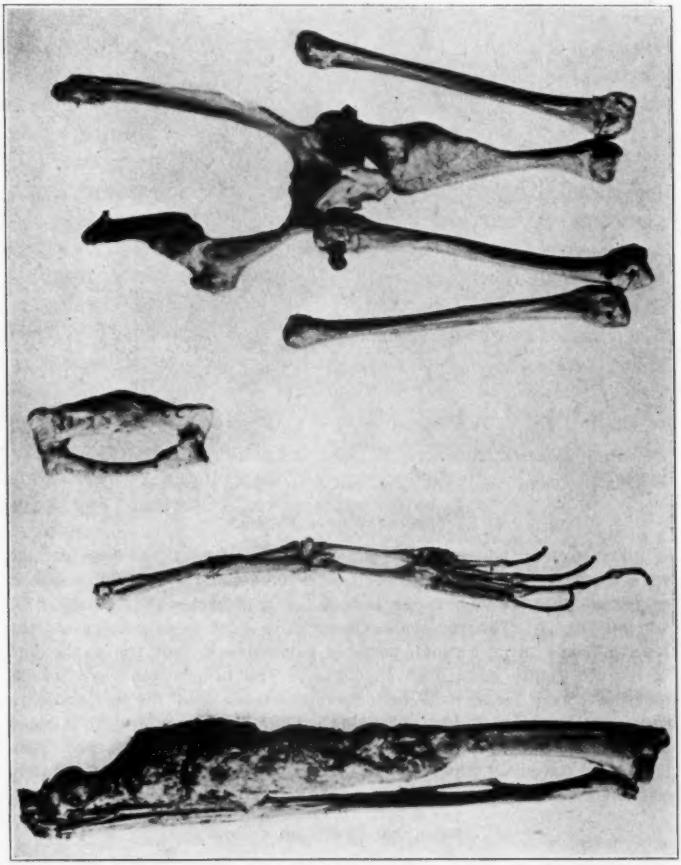

FIG. 2. *(Top).* Femur and ilium of a frog, *Rana catesbiana. (Middle).* Calcaneum and tibio-fibula of *Rana climatans. (Bottom).* Ulna and radius of a mallard, *Anas boschas.*

CALCANEUM AND TIBIO-FIBULA OF A FROG

(Rana climatans)

The left calcaneum has been fractured but has made a good recovery. There has been no slipping of the broken ends because of the

articulation with the astragalus and the ankylosis of these bones. The callous is small, and the fracture seems to have caused no mechanical disturbance.

The left tibio-fibula shows a bad fracture and a very good repair. In this case there was a splintering of the bone, but the recovery has been good with little shortening and with a small callous in comparison to the seriousness of the break. The repaired bone is not far out of alignment, and the shortening is not enough to interfere with the proper functioning of the limb. It is evident that the pull of the muscles in this segment of the leg is not as strong as in the femur, so that overlapping of the broken ends is not so likely to occur.

ULNA OF A MALLARD

The broken ulna of the right wing probably was caused by a gunshot wound. The wound was several months old at the time the specimen was collected, for repair was still in progress, judging from the large callous present. The wing was functional in this stage, and in a few more months it would have enabled the bird to fly again, although it would not have been strong enough for a long migration. The wing would have been normal in its activity except for a partial loss of power in supination and pronation.

MANDIBLE OF A DOMESTIC SHEEP

The broken jaw appears to have been the result of a gunshot wound. From the appearance of the healed break, there was a complete fracture of the dentary a little anterior to the midline, between molar 1 and premolar 3. The jaw repaired itself, judging from the teeth, and the animal lived to an old age. For a long time after the injury, the animal probably had to use the right side of the jaw in mastication, since the break caused a change in the relations of the teeth so that the occlusion was far from normal; but since the teeth on the broken jaw are worn, it is probable that the problem of occlusion eventually solved itself by an adjustment of the surfaces of the teeth. The jaw is completely repaired, with little trace of callous remaining.

FEMUR OF A DOG

The fractured left femur is completely repaired, though there is some callous remaining. The break was in the proximal third of the shaft, where there was not the opportunity to pull the bone out at an angle as in the following example, where the fracture is in the middle of the shaft. The ends of the bone were overlapped, so that the leg was shortened about an inch, and there was a torsion of about 30° in the proximal end, so that the foot must have been twisted. As a result, only the outer edge of the foot would touch the ground in walking unless there was some adjustment in other parts of the leg to lessen this defect. This repair allowed fairly good use of the leg,

except that the shortening and twisting would prevent some normal activities. The animal would be able to live but it would not have its former speed.

FEMUR OF A CAT

The femur shows a healed fracture at about the middle of the shaft, with some displacement of the fractured ends. This type of repair is usual in both the humerus and the femur because of the strength of the muscles and the way in which they are inserted. The distal end of the femur has been pulled so that it is out of line about

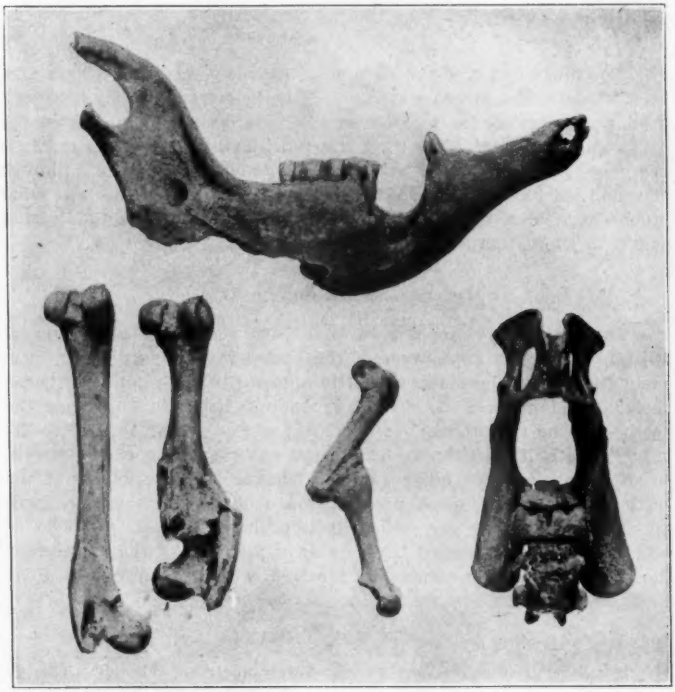

FIG. 3. *(Top).* Mandible of a domestic sheep. *(Bottom, left to right).* Normal femur and broken femur of a dog, broken femur of a cat, and lumbar vertebra of a lynx.

60° and has slipped down so that it is joined to the anterior face of the shaft and ankylosed. This caused a shortening of about ¾ of an inch and a torsion of the distal end of about 40°, which would throw the sole of the foot out and make the animal walk on the inside border. The result was a great physical handicap, making it necessary for the animal to have a rather restricted range.

LUMBAR VERTEBRAE OF A LYNX

The lumbars in this specimen suffered from injury or disease, for there is a small ankylosis of the last two lumbar vertebrae, with a small amount of callous tissue. The mechanical disadvantage in this case would be small and the defect a minor one with only a slight stiffness in the hip region.

LUMBAR VERTEBRAE OF A HORSE

Fractures of this type occur in domestic animals to some degree, usually as a result of injuries, and they produce a growth of callouses over the injured parts. The postzygapophyses and the prezygapophyses

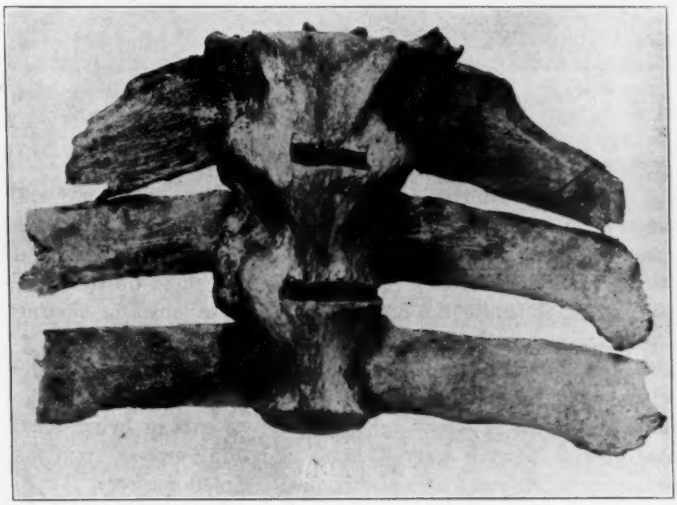

FIG. 4. Third, fourth, and fifth lumbar vertebrae of a horse, ventral view.

are ankylosed, and the centra of the three are securely joined in this way. These callouses are smooth, and did little more than to stiffen this region of the vertebral column. It is probable that the callouses occur at points where the bone was splintered or roughened.

RIBS OF A GORILLA

This specimen, from the Cameroons of Africa, was a male of perhaps 25 years. The skeleton showed signs of injury in a number of places, including a finger that had been badly infected with an extensive erosion of the bone, a fracture of the frontal bone, and a pair

of ankylosed ribs. The thirteenth vertebra of the thoracic region had the ribs ankylosed to it, the right very rigidly joined and the left with a light attachment and callous. There is evidence of a serious injury to the spine, in which the left prezygapophysis was broken, and a slight bend in the neural spine. This injury, although severe, would not interfere seriously with the activities of the animal.

FIG. 5. Thirteenth thoracic vertebra of gorilla.

HEALING PROCESS

The process of healing fractures is the same in other vertebrates as in man. The parts concerned in the regeneration are the inner layers of the periosteum, the bone cells lining the Haversian canals, and the endosteum. Outgrowth from these tissues dovetail and firmly unite the broken parts, and callouses of varying size are formed to hold the bone while in the process of mending. The osteoclasts remove the extra bone and reduce the size of the callouses to a minimum in the finished structure. Experiments by Bast, Sullivan, and Geist,[1] consisting of saw cuts in living bone, have showed in detail every stage of the healing process, from the temporary filling in of tissue to the final complete recovery.

CHANCE OF RECOVERY

Only a small number of animals have a chance for recovery when seriously injured, for many enemies are waiting for just such an opportunity. Some animals because of their habitat are more successful in hiding than others, and on this depends their survival when injured. The larger running animals have only small chance of recovery, for carnivores quickly locate and kill the wounded. Not being able to follow the herd, they are soon isolated and offer little resistance to pursuing enemies.

Arboreal animals may hide successfully while convalescing and thus survive. The smaller animals usually recover from

broken bones, since they can find secluded spots and can secure food with little exposure. However, if crippled, they must remain hidden; for a host of enemies, both furred and feathered, are constantly on the watch for such cripples. Water birds ordinarily have a good chance to survive, but they are hunted both on land and water by hawks, owls, and small carnivores such as mink, foxes, coyotes, and weasels. Reptiles and amphibians make a quick recovery and usually survive serious injuries because of their great recuperative and regenerative powers. They can hide successfully and thus have ample time for recovery.

Besides the natural injuries, the gun and the trap are responsible for the greatest number of crippled animals and birds. Birds and animals are shot at long range, suffering flesh wounds and fractures that permit them to escape, and often travel for miles from the place where the injury was received. This permits them to select a desirable spot in which they can hide until recovery or death.

The trap is responsible for many injuries to fur animals. Unfortunately, most traps permit the animal to die of exposure between the visits of the trapper. Some of the traps are so set that the animal, when caught, can exert no pressure and, hence, cannot escape by pulling off a part of a foot. Where the foot is crushed, the animal frequently succeeds in pulling away and generally recovers, because the crushing of the bones and blood vessels allows only a small amount of blood to be lost. Many animals caught in a country where trappers are numerous, show the results of previous experience in traps by mutilated feet or toes.

A survey of the literature dealing with fractures in wild animals seems to show that accidents and fractures are very numerous in the Artiodactyls, especially the deer group. Korschelt and Stock,[2] in a paper on fractures, list the following cases: Primates 15, Carnivores 18, Rodents 7, Artiodactyls 55, Cetacea 1, Birds 32, Reptiles 1, and Amphibians 3.

[1] Bast, Sullivan, and Geist. The Repair of Bone. Anat. Rec., Vol. 31, No. 25, 1925.

[2] Korschelt and Stock. Geheilte Knochenbrüche bei wildlebenden und in Gefangenschaft gehaltenen Tieren. 1928.

THE NATURE AND FORMATION OF SCALE INSECT SHELLS

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The armored scales (Coccidæ, Diaspinæ) are among the most interesting of all insects. They are the most specialized and anomalous of all known Homoptera. The remarkably degenerate structural condition of the females, which is correlated with, and in some way caused by, their sedentary habits, has resulted in an extraordinary sexual dimorphism, or pronounced structural difference between males and females (Fig. 1, *f* and *g*). Their great destructiveness to fruit and shade trees, ornamental shrubs, and florists' stock has also led to very extensive study of these insects.

Two questions of scientific and practical importance, however, appear not to be satisfactorily answered in the American literature dealing with the armored scale insects. *First,* what is the composition, or chemical and physical nature, of the shell or scale that covers the bodies of the insects; and *secondly,* how is the covering scale formed about the insect?

It has been well known that the secretion which forms the shell or case exudes from glands opening chiefly at the posterior end of the body (Fig. 4). We became interested in the question how a legless and presumably motionless insect can distribute a substance, formed at its tail end only, uniformly and symmetrically around the body in more or less concentric rings or crescents of increment as growth proceeds. It is also difficult to account for the actual mechanics of formation of a hard shell that completely covers the body of the insect making it, and yet allows for a steady and continuous growth. Does the wax, in a molten condition, flow out to the margins of the body; is it forced out by the weight of the shell already formed; or is it placed about the margin by some part of the insect's body? The American literature seems strangely silent on this point. None of the general texts nor the special bulletins on scale insects that we have consulted attempt to explain how the female insect places her secretions around the body. An American monographic work of 500 pages on the Coccidae contains

* Contribution from the Entomological Laboratories of the University of Illinois, No. 139.

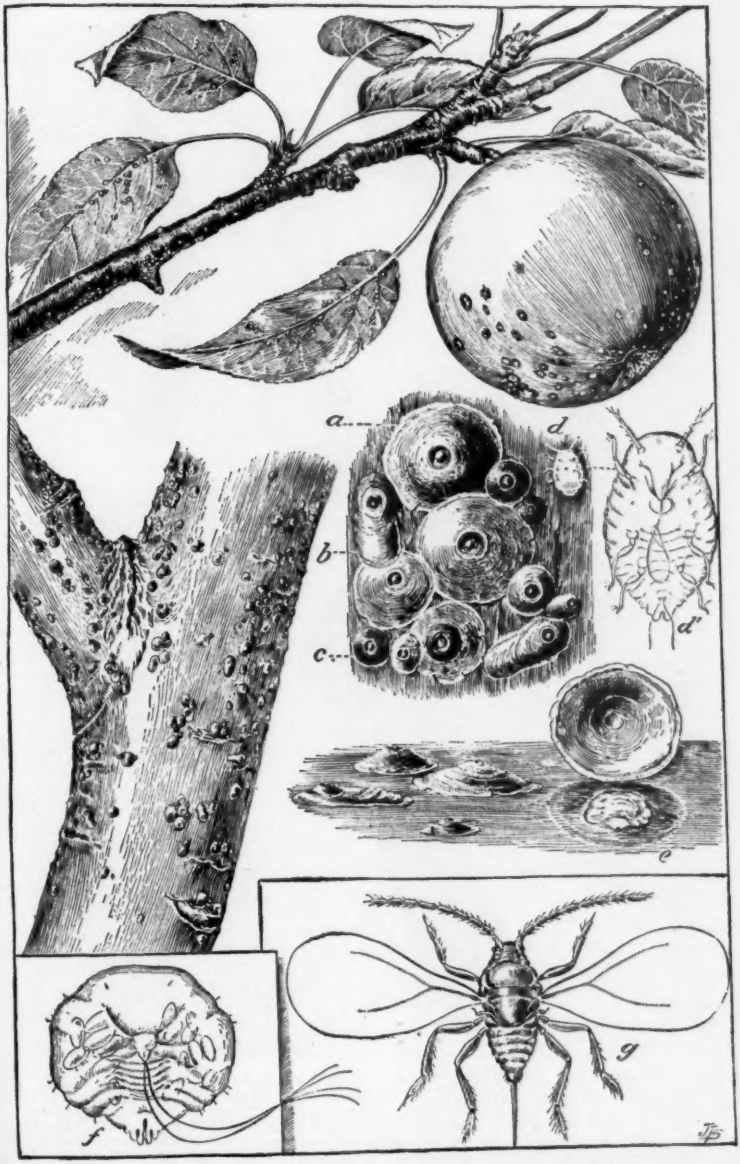

FIG. 1. The San José Scale: *a*, shell covering adult female; *b*, more elongate shell covering the developing male; *c*, shells covering young scales; *d*, first instar nymph or "crawler"; *d*, the same, much enlarged; *e*, shell lifted to show the body of the female beneath; *f*, body of the adult female, more enlarged; *g*, adult male. *(From U. S. D. A. Farm Bul. 650.)*

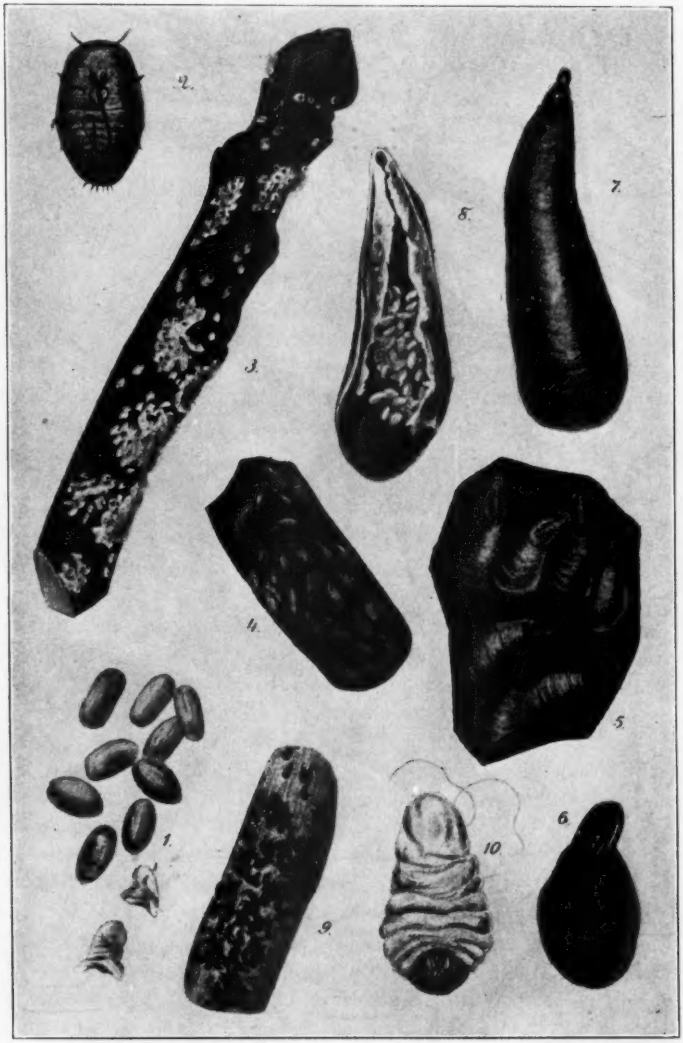

FIG. 2. The Oyster Shell Scale: (1) eggs and two shriveled shells, very much enlarged; (2) first instar nymph or "crawler"; (3) first instar nymphs after settling on the bark, showing the whitish threads that form over the back of the first nymphs; (4) partly grown scales with an old one; (5) a group of partly grown scales, more enlarged; (6) shell covering the developing male—note the single terminal exuvia, and the lines of growth on the shell; (7) shell covering the adult female—note the two exuviae at the anterior end and the lines of growth on the shell; (8) shell of female turned over, showing remnants of the ventral shell, the eggs filling most of

not a word on this point. Inquiry among a number of entomologists revealed to us a general lack of understanding of this point. We, therefore, present the following contribution toward a wider understanding of this interesting question.*

To anyone examining one of the armored scales, it is obvious that the shell is composed of two different parts. One part is clearly the shed skin, or exuvia, of the young insect. The other part is as clearly an amorphous plate or shell and, upon microscopic examination, the latter is seen to be knitted or spun from innumerable threads which are so closely interwoven, or packed together so tightly as to appear like little pellets held together by minute threads to form a firm membrane. (Fig. 8.)

There are two principal types of these shells or scales; one (Fig. 2, *6* and 7) in which the exuviae occupy a position at one end, with most of the shell developed in concentric bands toward the other end ("exuviæ terminal"); and another (Figs. 1 and 5) in which the shell is more or less uniformly distributed in concentric rings about the central exuviae. Various intermediate conditions are found in which the exuviae are more or less eccentric but not terminal.

Before proceeding to a discussion of the formation of these shells we may review briefly the events in the life-cycle of the insect which are necessary to an understanding of the nature of the scale or shell. Eggs are laid under the shell, as in the Oyster Shell Scale (Fig. 2, *1* and *8*); or the young are born as active crawling nymphs without any exposed egg stage. The minute nymphs (Fig. 2, *2;* and 1, *d* and *d'*), which are provided with six, well-developed legs, a pair of long antennæ, large simple eyes, and functional piercing-sucking mouth parts, are indistinguishable as to sex. They crawl about over the host plant for a few hours during which they may succeed in covering a few inches to a few feet distance.

Natural dispersal is entirely restricted to these minute nymphs or "crawlers." Their period of activity rarely exceeds a few hours and the distance covered is, ordinarily only a few feet. When an appealing spot on the host plant is found the nymph inserts its

* Since this article was submitted for publication, an article by Moriyuki Matsuda, "Studies on *Chrysomphalus aonidum* L. in Formosa," has appeared as Report No. 39 of the Dept. Agr. Gov't. Research Institute, Formosa, Japan, April, 1929, to which the reader is referred.

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the shell and the dead shriveled body of the female at one end; (9) a group of female scales; (10) body of adult female removed from shell. *(From New York State Museum Bul., Vol. 9, No. 46, 1901.)*

mouthparts and, in the case of the female, the individual ordinarily never again moves from that spot. Since the flight of the adult male has no significance in dispersal, the natural spread of armored

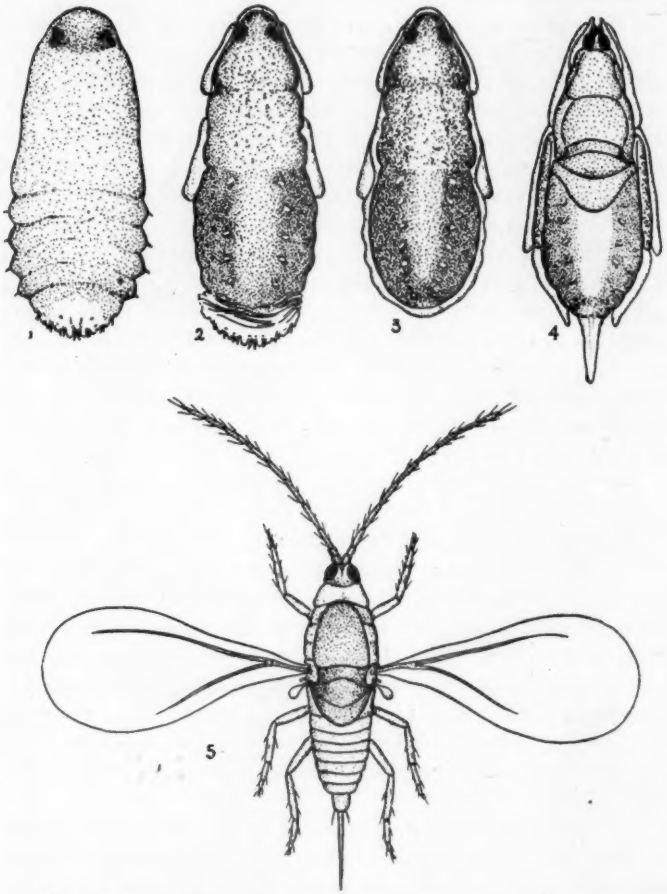

FIG. 3. The Purple Scale, *Lepidosaphes beckii* (Newman), showing the stages in metamorphosis of the male: (1) second stage nymph; (2) third stage nymph with exuvia of second stage adhering to tip of abdomen; (3) the same without exuvia; (4) fourth stage nymph; (5) adult male. All dorsal views and greatly enlarged. *(From Cal. Agr. Exp. Sta. Bul. 226.)*

scales is extremely restricted, and plants attacked become very heavily infested and frequently killed. The transportation of host plants has, however, carried some species to the ends of the earth.

As these first stage nymphs, which are mere specks in size, begin to feed, threads of a secretion from unicellular glands opening thru the skin appear over the back and soon completely cover it with a cottony mass (Fig. 2, *3*). These threads may break off and blow away. Sometimes, however, they mat down or fuse into a delicate, transparent membrane, or form a whitish knob or raised ring on top at the center of the scale. This is the uppermost and first part of the compound shell and some trace of it usually covers the exuviæ. Shortly after feeding begins, the first molt occurs, the insect splitting off its skin and slipping out on the under side leaving the dorsal part of its exuvia in place over its back to form the nucleus, nipple, or so-called exuvia of the scale.

At this first molt resemblance between males and females, which up to this time were indistinguishable, begins to disappear. The female loses her antennae, eyes and legs, nearly all trace of body regions and segmentation and becomes a mere bag of living substance with a sucking tube, formed by the mouthparts, at the middle of the under side of the body, as her only remaining appendage (Figs. 1, *f;* and 2, *10*). The female insect thus loses permanently nearly all of the characteristics of the class Insecta to which she belongs.

The metamorphosis of the female is a very simple one. The egg produces the active, six-legged, first instar nymph. The first molt transforms her to a sessile, legless, second instar nymph, like the adult except smaller in size, in being devoid of a genital orifice, and in lacking circumgenital glands. A second and final molt discloses the adult female (Figs. 1, *f;* and 2, *10*).

The males undergo a much more pronounced metamorphosis. At the first molt, which terminates the active, crawling, first nymphal stage and initiates the second instar, the male appears (Fig. 3, *1*) without legs, antennae and eyes, and is in a general way similar to his sisters although the body and the shell that covers it, is usually somewhat more elongate. After a few days the males molt again and in this third instar (Fig. 3, *2* and *3*) have lost all resemblance to the females. The mouth parts have entirely disappeared and the males never feed after this stage. They are somewhat pupa-like: the developing legs and antennæ, which arise from histoblasts, show externally, each enclosed in a separate case. They molt again, the legs and antennæ becoming larger, and the wing pads appear (Fig. 3, *4*). A conical projection at the tip of the abdomen contains the genital apparatus.

After a fourth and final molt the two wings expand beneath the shell and, according to Green (*l.c.*), the males crawl out backward, drawing the delicate wings up over and in front of the head. It is interesting to note that the wing pads are borne externally, thus properly placing the Coccidæ, along with other Homoptera, as exopterygota.

A comparison of adult males and females reveals the following extensive dimorphism:

Adult Male (Figs. 1 *g*; 3, *5*)	Adult Female (Figs. 1 *f*; 2, *10*)
Body insect-like with body regions evident.	Body gall-like, sack-like or scale-like with body regions indistinguishable.
A pair of large front wings. Hind wing rudimentary, usually consisting of a hook which engages a small pocket near the base of the front wing.	No trace of wings.
Three pairs of well-developed legs.	No trace of legs.
A pair of very rudimentary compound eyes and two pairs of ocelli or simple eyes, one on the dorsal and one on the ventral side of the head.	No trace of eyes.
Antennæ large and well-developed.	No trace of antennæ.
No mouth parts; takes no food. The male thus lacks the only appendage that the female possesses.	Mouth parts well-developed, often several times as long as the body. They consist of four stylets (the two mandibles and two maxillæ) which form a piercing organ and a sucking tube. When not inserted into the plant, the stylets lie in a delicate-walled invagination of the head forming a pouch into which they coil or loop before entering the plant tissues and in which all the slack of the stylets is held. The labium is greatly reduced and forms a tiny triangle at the base of the stylets.
Only one exuvia incorporated in the shell which is usually more elongate or more slender than that of the female (Fig. 1, *b*; 2, *6*).	Two exuviæ incorporated in the shell (Fig. 1, *a*; 2, 7.

The male has a prominent genital spike or sheath, which is slender and pointed and may be half as long as the body. It consists of a single piece with the margins rolled ventrally to form

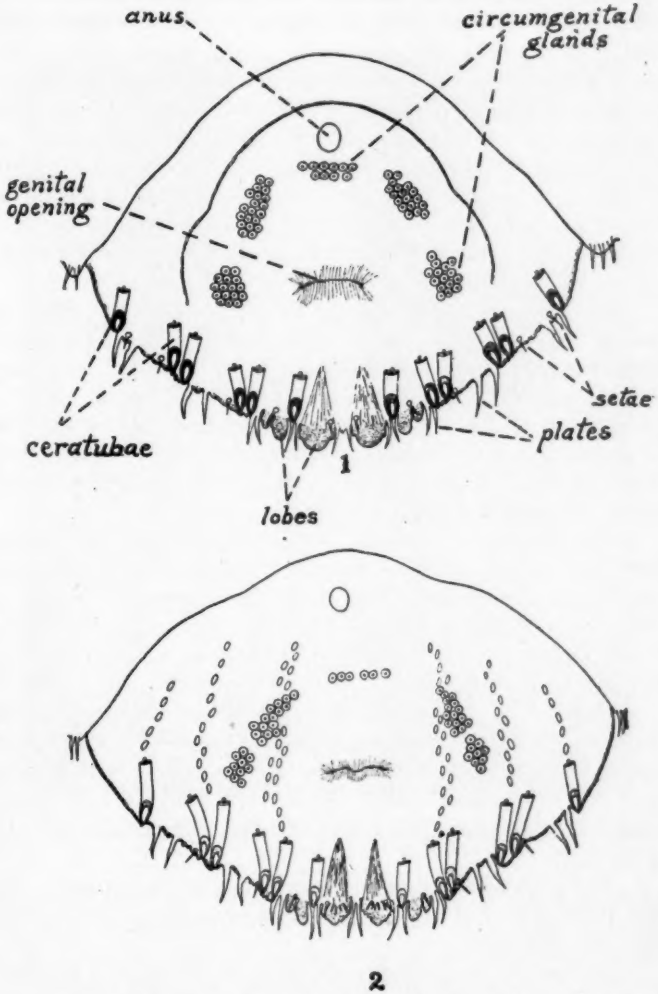

FIG. 4. The pygidia of two closely related scale insects: the Oyster Shell Scale, *Lepidosaphes ulmi* L., *above;* and the Purple Scale, *Lepidosaphes beckii* Newman, *below.* The genital opening and circumgenital glands show through from the ventral side. The secretion which forms the shell is poured out through the ceratubæ. *(From Miss. Agr. Exp. Sta. Tech. Bul. 2.)*

an incomplete tube through which the very elongate flexible penis is exserted to fertilize the female beneath her shell.

The pygidium of the female (Fig. 4) is a flattened, terminal portion of the abdomen, somewhat triangular, and more chitinized than the rest of the body. It consists of four to possibly eight coalesced segments. At the middle of the under surface is the female genital opening, surrounded by the openings of the *circumgenital glands,* often arranged in five groups. These glands are absent in many species, e.g., in the San José Scale, so it is obvious that they cannot be the glands that secrete the shell. Green (*l.c.*) has shown that in species where they are absent the young are produced ovoviviparously, while those species which have them lay eggs. He believes their function is to secrete a powdery substance for protection of the eggs.

On the dorsal surface of the pygidium is the anus. On this surface open the spinnerets or ceratubæ, the openings of the glands from which the covering shell is produced. These glands open thru longer or shorter invaginations of the cuticle that form very delicate chitinous tubes. The inner end is capitate or bulb-like, with a chitinous tongue communicating with the non-chitinous duct from a unicellular gland, called a silk gland by Berlese, but which we do not believe is silk.

Surrounding the opening of this silk (?) gland are others with shorter ducts and secreting a different substance, which has been called a varnishing or cementing material that we believe to be a true wax. The secretions of these different unicellular glands blend together in the ceratubæ and form an intimate mixture which constitutes the shell.

The margin of the pygidium bears a variety of spines and setæ and plates that are valuable taxonomic characters. There are in the various species (Fig. 4) from one to four pairs of lobes, various incisions with ventral thickenings of their margins, and simple spine-like or pectinate plates, each of which contains the outlet of a gland.

The development of the shell covering a typical armored scale like the Florida Red Scale, *Chrysomphalus aonidum* Linné, (Fig. 5) is now followed.

At the time of the first molt, the body increases in size and to cover it an extension is made all around the shed skin or exuvia, consisting of closely woven filaments, so packed together as to form a very firm but thin shell or membrane.

This second addition to the shell is in the form of a disc with a hole at its center, since the secretion does not extend over the middle region or back of the second instar nymph. The first exuvia is more or less covered above with the secretion formed during the first nymphal instar; its margins fit into the disc formed

FIG. 5. The Florida Red Scale, *Chrysomphalus aonidum* L., showing scales of adults and nymphs of various sizes on palm leaf. Note the central exuviæ and the indications of successive rings of growth on the larger scales. *(From Mich. Agr. Exp. Sta.)*

by the second nymph much as a crystal fits in the face of a watch; but it is exposed on the under side except for a little secretion which formed a very thin ventral scale for the first instar nymph.

After a period of feeding and growth during which the shell or covering scale keeps pace with the increase in size of the body, a second and last molt takes place, the insect slipping out beneath

as before and assuming its final form called the adult. This is very similar to the second stage nymph, except that it is much larger.

The second shed skin, like the first, becomes incorporated in the scale, being cemented to the upper and earlier part by its margins only and by the very thin ventral scale of the first instar nymph. At this stage copulation with the winged male occurs. The

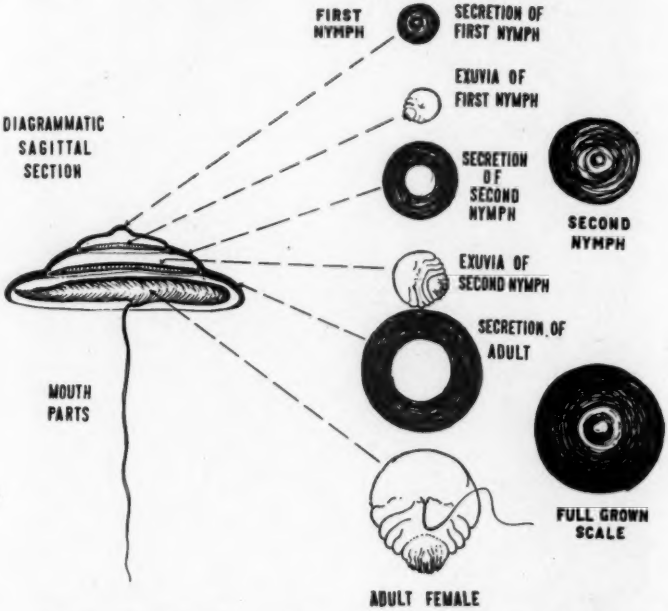

FIG. 6. Diagram to show the structure and development of an armored scale. *(Original.)*

fecundated female expands in size, outgrowing her covering, and another and final addition is made to the house. This is added as a concentric ring or band around the margin of the second exuvia, and not extending across the middle region.

The scale is thus seen to consist of five distinct parts or increments (Fig. 6): (1) the secretion over the back of the first instar nymph, which is sometimes largely worn away; (2) the shed skin of the first nymph; (3) the flattened ring of secretion made by the second instar nymph; (4) the shed skin of the second instar nymph; and (5) the flattened ring of secretion made by the

adult female. Finally, beneath all this, is the living body of the female.

When the complex composition of the scale was discovered, the problem of how it was formed became all the more puzzling. As stated above, all the American literature known to us is strangely silent on this point.

It became evident to the authors that the only theory that could account for the symmetrical distribution of the secretion, from glands opening only at the anal end of the body, is that the legless female must rotate her body completely around in a circle beneath her shell, painting the semi-fluid secretion in concentric rings as she goes. After having formulated this theory, we discovered in Green's monographic work (*l.c.*) the following statement:

> "In some genera, such as *Aspidiotus* and *Diaspis* .....the insect must revolve completely around the point of attachment during the construction of the puparium. In the genera forming elongate puparia, a to-and-fro sweeping motion of the hinder parts of the body is sufficient to produce the resulting form of scale."

Berlese in *Le Cocciniglie Italiane* says (translation):

> "The larvæ of *Aspidiotus* and *Aonidiella* form the first layer of silk, perfectly circular, and may get this shape by turning around, while spinning, upon the center of their bodies as an axis.
>
> "In *Aspidiotus* and *Aonidiella* all the species spin by turning around upon themselves; therefore the dorsal scale and the leaf-like ventral scale are composed of threads which combine into so many concentric circles and are discoidal in form.
>
> "In *Mytilaspis* and *Parlatoria zizyphi*, however, the insect spins while swinging the body in a light oscillating motion from right to left, from which the threads form as many crescents in a row and the whole shield is drawn out in length rather than being round."

Contrary to the supposition of many people, the female, altho legless and sedentary, is not motionless. Proof that this theory is correct was found by soaking the scales in potash solution when they could be separated by careful dissection into their component parts. Since the pygidium is recognizable in each of the molted skins and the posterior end of the body thus definitely marked, it

is obvious that if the three do not all point to the same point of the compass, the body of the insect has rotated.

Examination of a number of scales gave the following results. As the shell was lifted, the position of the adult pygidium was marked with a notch in the margin of the shell. After soaking in potash the corresponding posterior end or pygidium in the first and second exuviæ could be seen. Taking the position of the adult pygidium as 12 o'clock in each case, those of the nymphs in five unselected cases stood as follows:

Adult	12	12	12	12	12
2nd Nymph	6	11	3	10	9
1st Nymph	2	8	1	7	4

How the body moves, whether clockwise or counter-clockwise, or how many times it completes the circuit we do not yet know. The examination of the shells of certain species shows some evidence of successive rings arranged in a spiral (Fig. 5), which indicate that the adult insect rotates at least several times during her life. The complex lobes, spines, and the plates of the pygidium (Fig. 4) may be used as prys or prickers to gain leverage against leaf or bark and enable the insect to push her muscular body sidewise, while it is anchored at the center by the mouth parts. They serve as bristles of a paint brush, the pectinate and spine-like plates having wax glands opening in their margins. Is it possible that their complex nature is in part correlated with the nature of the leaf or bark surface over which their lubberly bodies must shift?

In the case of a scale with exuviæ terminal (Fig. 2, *6* and 7) it is obvious that the tip of the body is simply lashed from side to side as the secretion exudes and the increments are painted on in successive crescents.

The other question as to the composition or chemical and physical nature of the secretion which forms the major part of the scale, is quite as unsatisfactorily answered in the literature. Nearly all the literature we have consulted refers to the scale of the Coccidæ as a wax or waxy secretion. Berlese speaks of it as spun silk excreted from the rectum. Green calls it "waxy, fibrous or resinous matter." It was probably the general opinion regarding its waxy nature that led Maulick a few years ago to attempt the solution of the scale in wax-solvents in the hope of improving the known insecticides for scale insect pests. He immersed twigs of elm, bearing Oyster Shell Scale (*Lepidosophes ulmi* Linné) in

each of 17 different known wax solvents for nearly a year. At the end of this time he reports that no action seemed to have taken place and he concluded that the scale is most probably not a wax.

In our investigations the Oyster Shell Scale (*Lepidosaphes ulmi* Linné) was gathered by scraping from common Lilac (*Syringa vulgaris*) and extracted in a Soxhlet extractor. Ether extracted only 11% of the total weight of the dried scales and, since the eggs and dead bodies would furnish considerable fatty matter, it was evident that but little wax had been taken from the scales themselves. Carbon tetrachloride extracted an additional 24% of the original weight of the scales, making a total of 35% of the weight of the scales which yielded to wax solvents. Since a considerable portion of this might have come from the dead females and eggs remaining as a contamination of our material, we next undertook the tedious task of scraping out eggs and dead bodies of females from a quantity of these shells, leaving only the clean shells and their exuviæ.

These yielded to extraction with hot carbon tetrachloride 58% of their original weight. Next some of the scales were taken and the exuviæ cut off, leaving nothing but the pure secretion of the female insects. This gave, with hot carbon tetrachloride, 71.8% wax dissolved out. This shows that there is less wax, if any at all, in the exuviæ.

After extraction of the wax with carbon tetrachloride the scales looked somewhat lighter in color and were slightly shrunken in size but the fact that no great difference in appearance results is shown by the picture (Fig. 7) of the twigs bearing scales, two of which were extracted by carbon tetrachloride until no more wax could be removed, the others untreated. Microsections of the extracted scale (Fig. 9) showed the insoluble part to be homogeneous in structure and tending to split into layers which however show no signs of uniformity and are doubtless irregular planes of weakness in the scale. It is now quite clear why Maulick recognized no change in the scales which he treated with wax solvents for a year. Even though a considerable quantity of wax had been extracted the gross appearance of the scale would not have been appreciably altered. It is only when one compares a micro-section of an extracted with an unextracted scale that one sees where the wax has come from. The relation between the cross-section of the extracted and unextracted scales is shown in figures 8 and 9.

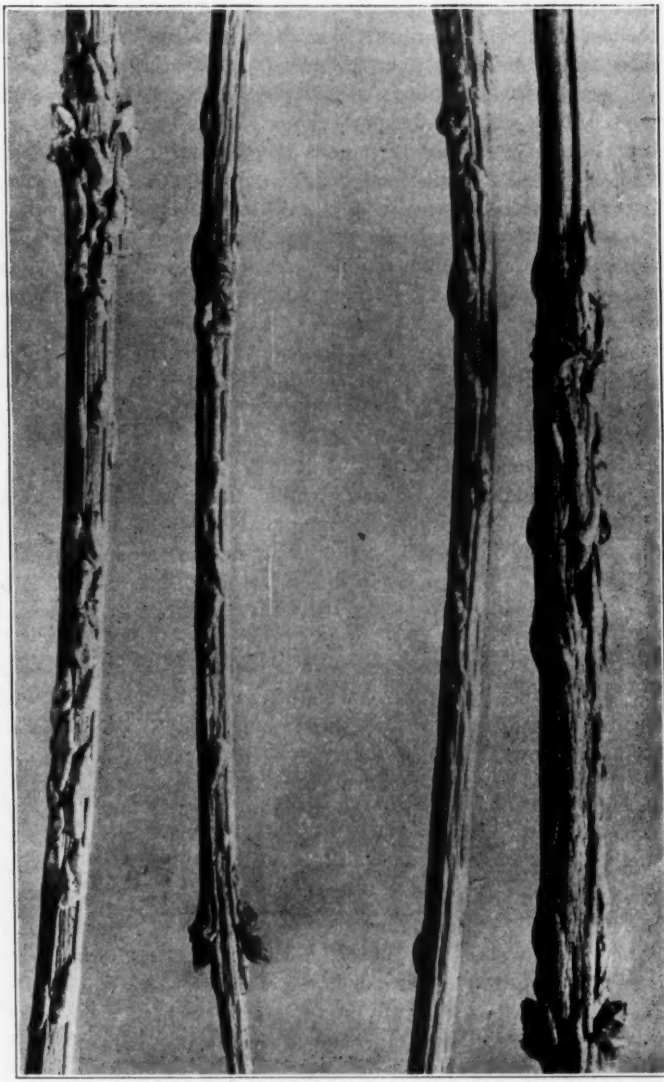

FIG. 7. Twigs of Lilac bearing Oyster Shell Scales. The two twigs on the left have been treated with hot carbon tetrachloride until one-third of the weight of the scales has been extracted; the other two twigs have not been treated. Note that the loss of one-third the original weight of the shells has scarcely altered their gross appearance. *(Original.)*

The part of the scale left after extraction with carbon tetrachloride was tested for chitin by the method suggested by Campbell (1929) and gave negative results. The extracted scales became colorless and then dissolved in the concentrated potassium-hydroxide solution used in this method. It was thought possible that the scales might merely have disintegrated into a colloidal

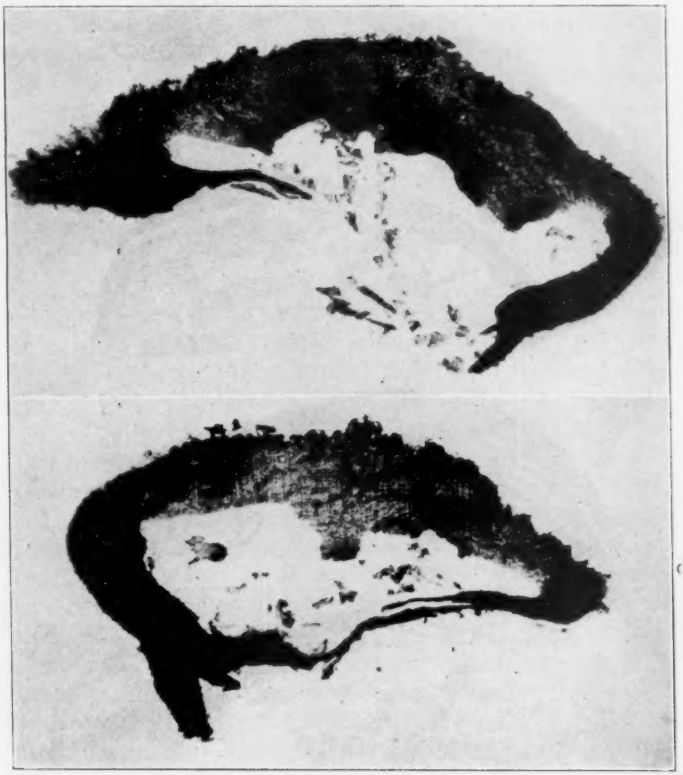

FIG. 8. Two microsections of an Oyster Shell Scale, which had not been treated with wax solvents. Compare Figure 9. *(Original.)*

state; but when the alkali was neutralized with acid and the solution evaporated to dryness the only material left that gave a test for chitin was the exuviæ, which had not dissolved or disintegrated. Scales, which had been extracted with carbon tetrachloride but not boiled in alkali, gave negative tests for protein, using Millon's

reagent and the xanthoproteic test. Attempts to hydrolize the scales and recover amino acids also failed; but a sodium fusion test showed the presence of nitrogen. The exact chemical nature of the non-waxy part of the scale is thus left in doubt.

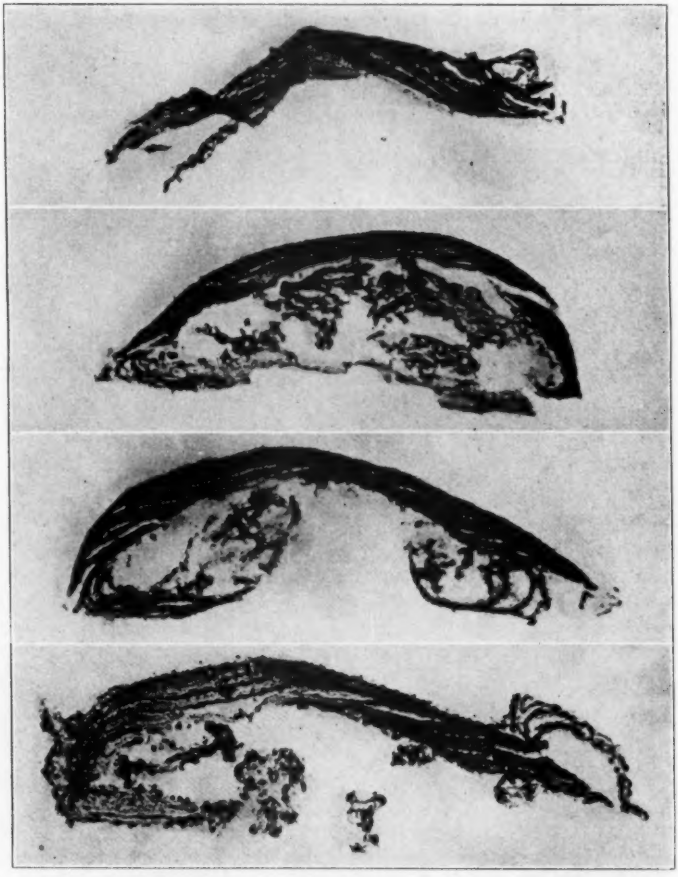

FIG. 9. Microsections of Oyster Shell Scales after treatment with hot carbon tetrachloride to extract the wax. Note the splitting of the shell into layers. Compare Figure 8. *(Original.)*

A similar extraction was carried out on the Florida Red Scale (*Chrysomphalus anonidum* Linné) as collected from two different host plants, namely Kentia and Dracenæ. The wax totalled 31% and 34% respectively, in the case of the scales collected from

Kentia and Dracenæ. Since this difference is within the range of probable error it indicates that the nature of the shell is specific for the insect and unaffected by the host plant. The Pine Leaf Scale (*Chionaspis pinifolia* Fitch) gave 40.3% extracted wax with carbon tetrachloride while the Fluted Scale (*Icerya purchasi* Mask.) gave 98% or more of wax, being nearly pure. Some extractions of the exuviæ alone showed that little or no wax was contained in this part of the scales. It was further found that the scale once extracted could not be made to reabsorb any of the wax.

The solubility at room temperature of the Oyster Shell Scale wax in grams per c. c. was found to be:

With ethyl acetate	.0059
With ether	.0084
With carbon tetrachloride	.0008
With carbon disulfide	.0041
With ethyl alcohol	.0005

The waxes were readily soluble in carbon tetrachloride only at high temperatures near the boiling point, ether being a better solvent *at room temperature* than carbon tetrachloride.

The wax was found to be a mixture in all cases and to be specific for each insect even though they had fed on widely different hosts. The wax from the Oyster Shell Scale melts at 94-96° C. and this lack of a sharp melting point shows it is not a pure compound, but a mixture of several waxes. The Florida Red Scale wax melts at 88-90° C., and the Fluted Scale wax fairly sharply at 80.50° C., and the Pine Leaf Scale at 86-88° C. The wax of the Fluted Scale thus differs from the others in that it seems to be nearly pure and is probably chiefly ceryl cerotate, which is known to be the chief constituent of "china wax," the commercial extract of a species of *Coccus*. Pure ceryl cerotate melts at 82.5° C. and pure china wax at 80-81° C. Some of the Oyster Shell Scale wax was partially purified by fractional crystallization and found to melt then at 98-99° C. There is only one known wax that melts at so high a temperature and this is cocceryl coccerate melting at 106° C. Hence, it seems highly probable that the wax of Oyster Shell Scale is largely cocceryl coccerate mixed with some other wax, probably of lower melting point.

CONCLUSIONS

The legless female insect underneath her skin is not motionless although she is quite sedentary. In the case of circular scales

her body rotates thru a complete circle at least once in each life-stage, as the secretion from her anal glands is distributed in concentric rings. In the case of elongated scales with terminal exuviæ the tip of the abdomen is lashed from side to side to distribute the secretion in successive arcs of larger and larger radius.

The scale of the female Florida Red Scale, which shows superficially as two parts, proves upon analysis to consist of 5 distinct increments: (a) A thin central disc lying above the first exuvia and secreted by the first instar nymph; (b) the exuvia of the first instar nymph; (c) the flattened ring of secretion made by the second instar nymph; (d) the exuvia of the second instar nymph; (e) the flattened ring of secretion made by the adult female.

The secretion which forms the hard covering of armored scale insects is an intimate mixture of a wax with some other material. The wax is specific for each species of scale, and varying in the cases tested from 30% in the Circular Scale, 35% in the Oyster Shell, and 40% in the Pine Leaf Scale, to 98% in the Fluted Scale. The remaining 65% of the shell of the Oyster Shell Scale is apparently not chitin according to Campbell's method, and the usual tests do not indicate silk or proteins, although nitrogen is certainly present.

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STUDIES ON THE LIFE HISTORY OF THE BLUNT-NOSED MINNOW*

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(Abstract)

1. A single collection of 369 specimens of the blunt-nosed minnow, *Hyborhynchus notatus,* was taken from a dredged tributary of the Black Slough in Champaign County by David H. Thompson of the Illinois State Natural History Survey and the senior author on April 27, 1928. The individuals have been subjected to statistical study and microscopical examination for age determination.

2. The fishes measured in standard length from 1.3 cm. to 7.9 cm.

3. The largest individuals are of the maximum size encountered in a collection of 6,440 specimens of the same species taken by Dr. Thompson from Champaign County.

4. Individuals under 4.5 cm. long are less than one year old with actual ages of from 8 to 11 months. This statement is based upon a microscopical examination of the scales and observations by Hankinson which indicate that in central Illinois this species has a breeding season extending from May 1 to August 26.

5. In specimens over one year, the males are regularly larger than the females; median for males 7 cm., for females 5 cm.

6. The oldest females are slightly under two years of age.

7. The oldest males are slightly under three years of age.

8. Females of the blunt-nosed minnow seem to have a single breeding season, which occurs in their second year.

9. Males of this species seem to be immature in their second year. Only the three-year-old males have well-developed testes and display the pearl-organ on the head. Males of the two-year age class and some of the smallest males of the three-year group lack pearl-organs entirely.

* The complete paper upon which this abstract is based, has been published in The American Naturalist, Vol. 63, No. 689, pages 530–539.

THE MOLLUSCAN FAUNA OF THE SOUTHERN PART OF LAKE MICHIGAN AND ITS RELATIONSHIP TO OLD GLACIAL LAKE CHICAGO*

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During a favorable period last winter Dr. A. R. Cahn, of the Department of Zoology, University of Illinois, secured a remarkable collection of beach material from the shore of Lake Michigan at the foot of Division Street in Chicago. A study of this material, and of some other material previously collected by the writer and others from the south shore of the lake, shows that we have in this area a distinct fauna of mollusks, containing at least 23 species and varieties, 11 of which occur only in lake waters in Illinois. The Pelecypoda contain 8 species and the Gastropoda 15 species and races, 10 of these 15 being found only in Lake Michigan.

Among the Pelecypoda, *Sphaerium acuminatum* appears to be a Great Lake dweller, at least as far as Illinois is concerned. Some of the Pisidia of the lake indicate special characteristics but these have not yet been varietally differentiated. Among the Gastropoda, all species and races excepting two are lake forms and ten occur only in Lake Michigan. Such species as *Valvata perdepressa walkeri, Bulimus tentaculatus magnalacustris, Amnicola limosa superiorensis, Cincinnatia cincinnatiensis chicagoensis, Vancleaveia emarginata canadensis, Pleurocera acuta, Goniobasis livescens, Goniobasis livescens michiganensis, Stagnicola woodruffi, and Physella integra billingsii* are typically Great Lakes dwellers. Several of these have their type localities in this part of Lake Michigan.

Nearly all of the varieties have evolved, apparently, from species which lived in Glacial Lake Chicago, and comparison with material from the Chicago deposits made accessible by the drainage canal operations in Chicago shows in nearly all cases the variety gradually developing from the Pleistocene species living in the colder waters of the glacial lake which preceded Lake Michigan. In fact, the Lake Michigan fauna is a direct descendant of the Glacial Lake Chicago fauna, the latter migrating up the Illinois

* Contribution from the Museum of Natural History, University of Illinois, No. 55.

and DesPlaines rivers in late Pleistocene time. So that the Lake Michigan fauna may be considered a direct response to the changing environment from a river, through a small lake and later a large bay, to the great lake which washes our shores today. As a study in geological evolution, embracing the element of time as well as of change in habitat, no place surpasses the Chicago region with its old lake deposits and its present large lake area. When studied from this standpoint the variations of river species found in the lake are perfectly understandable and they cannot be understood from any other angle.

I am indebted to Dr. V. Sterki for the determination of the Sphaeriidae and to Dr. A. R. Cahn for procuring the material. Dr. Cahn appears to have a special sense for acquiring critical material, a fact well attested by the many new forms found by him in Wisconsin in recent years. Changes in nomenclature used in this paper will be found discussed in the writer's Fresh Water Mollusca of Wisconsin, Bull. 70 of the Wisconsin Geological and Natural History Survey, issued late in 1928.

PELECYPODA

SPHAERIIDAE

Sphaerium acuminatum Prime.

This is the common Sphaerium of the lake, occurring in countless thousands on the shores of Illinois, Indiana, and Michigan. It has been erroneously recorded as *fabale* Prime and *vermontanum* Prime. Most of the Sphaerium from Lake Michigan belong to this species, the previous references to *flavum* being erroneous, according to Sterki. A distinct species about the size of *acuminatum* also occurs but is rare. It has not yet been described by Dr. Sterki

Pisidium virginicum Gmelin
Pisidium idahoense Roper
Pisidium scutellatum Sterki
Pisidium compressum Prime

These species are abundant on the lake shore. *Scutellatum* is said by Sterki to be the same as the European *Iilljeborgii* of Clessin. As *scutellatum* has been used largely in lists of American Pisidia and as it offers some differences, it would appear best to keep it separate from the European form, at least as a variety. Dr. Sterki reports the Lake Michigan forms to be peculiarly small with the beaks narrow, some with the scutellar angle not or barely marked. It would appear that the lake forms may be as distinct from the river forms as are some of the lake gastropods from the river forms of the same species. *Compressum* is a peculiar form, not the typical river form.

Pisidium noveboracense Prime
Pisidium walkeri Sterki

Both of the above species are rarely represented in the debris of the shore bordering Chicago. They were collected several years ago and named by Dr. Sterki.

GASTROPODA

VALVATIDAE

Valvata tricarinata (Say)

Specimens of the typical form occur rarely in beach debris.

Valvata perdepressa walkeri NEW VAR. (Text figure 1.)

Two forms of *perdepressa* occur in the southern part of Lake Michigan. One is the typical form with high spire and regularly coiled whorls. The other is a flattened, planorboid shell, the spire often depressed below the level of the body whorl. The first is common in the eastern part of the lake and the latter in the western part, especially on the Chicago shore. *Perdepressa* also occurs on the western shore of Lake Michigan on the Door County peninsula near Sturgeon Bay. In the Mollusca of Wisconsin, *perdepressa* is described as a variety of *bicarinata*, following Walker's opinion. An examination of the radula of *walkeri* shows that this reference is eroneous, *walkeri* having a smaller central tooth (65 microns wide) and a formula of 11-1-11, while *bicarinata* has a larger central tooth (80-85 microns wide) with the formula 15-1-15. The form of the shell is also quite different, the planorboid forms only remotely resembling *bicarinata* in the wide, shallow umbilicus. Variety *walkeri* occurs in the Pleistocene deposits of the Chicago area, the specimens, however, being smaller and not quite as planorboid as the recent lake form. They stand midway between typical *perdepressa* with the high spire and the flat form called *walkeri*. The fossil forms are doubtless ancestral to both *walkeri* and *perdepressa*.

It is apparent that the size of the center tooth is a good criterion for the distinction of some of the species of Valvata. The following table indicates this feature together with the cusp formula of the center tooth:

Valvata tricarinata	70	15–1–15
varieties	70	15–1–15
Valvata sincera	70	15–1–15
Var. nylanderi	70	15–1–15
Valvata lewisi	55	9–1–9
Var. helicoidea	55	9–1–9
Valvata bicarinata	85	15–1–15
Var. normalis	*85	15–1–15
Valvata perdepressa	65	11–1–11
Var. walkeri	65	11–1–11
Valvata winnebagoensis	45	10–1–10

Valvata sincera illinoisensis NEW VAR. (Text figure 1.)

In the Mollusca of Wisconsin a form of Valvata was referred to *sincera danielsi* Walker. The receipt of a large collection of Pleistocene fossils from the Illinois State Geological Survey indicates that this reference was erroneous. The fossil form is about half the size of *danielsi* and is apparently wholly extinct. It is a common species in the Pleistocene of Illinois and occurs more rarely in Late Wisconsin deposits in Wisconsin. The type locality is near the west end of Crystal Lake, McHenry County, Illinois, in a marl deposit of Late Wisconsin age. This variety does not occur in the Chicago deposits. It is probably the ancestor of both *sincera* and *danielsi*, but is nearer *sincera*.

Bulimus tentaculatus magnalacustris F. C. Baker

This species, usually so abundant in Lake Michigan, occurred but rarely in the Cahn collection. Also known in Pleistocene deposits in Chicago. For the reasons for considering this common circumboreal snail a race see the Mollusca of Wisconsin, I, page 81.

Amnicola limosa superiorensis F. C. Baker

This lake race of *limosa* occurs rarely in debris on the shore of Lake Michigan. It is more abundant in Lake Superior. See the Wisconsin Monograph I, page 101.

Cincinnatia cincinnatiensis chicagoensis New Var. (Text figure 2, *12-15.*)

This is one of the most abundant species in Lake Michigan, the shells occurring most commonly in any quantity of beach debris. It is a shortened-up race of the river form *cincinnatiensis*, differing in being more globose, with shorter spire and wide umbilicus. The radula is exactly like that of *cincinnatiensis*. This race also occurs rather abundantly in the Chicago Pleistocene deposits, but is slightly smaller. Typical *cincinnatiensis*, the river form, also occurs, and the variety *chicagoensis* is due to the forcing of the river form into the rougher waters of a large lake. This change of environment began when Glacial Lake Chicago was forming, the species having a chance to gradually change by living in a more or less protected environment in Wilmette Bay and behind bars and islands in Lake Chicago. *Chicagoesnsis* is an excellent example of the effect of a changing environment in directing the course of evolution.

Vancleaveia, New Genus.

Vancleaveia emarginata canadensis (F. C. Baker). Text figure 2, parts 3-5 and 10; also figure 3.

The difference in the center tooth of the radula and in the form of the spire whorls, flattened and coiled in the same plane, has led the writer to consider this group as a separate genus. The lower lateral ridge of the center tooth has three large cusps instead of one as in *Cincinnatia* and the lateral tooth has a larger number of cusps (Fig.

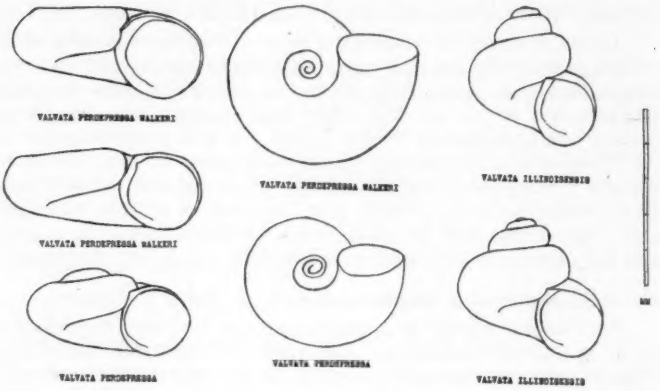

Fig 1. New forms of Valvata. (Camera lucida drawings).

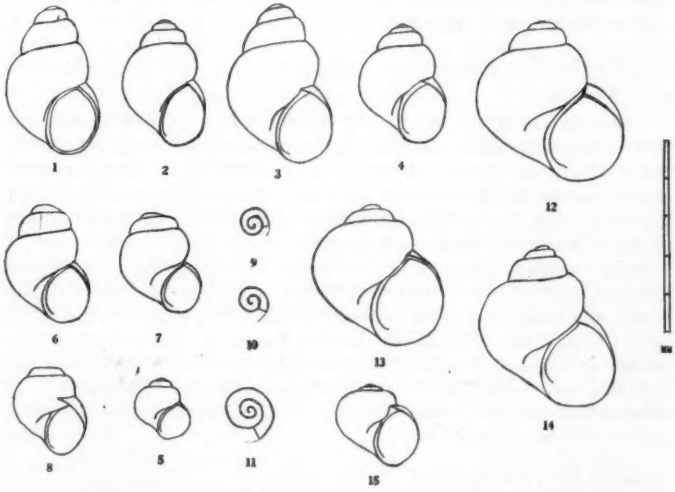

Fig. 2. *Vancleaveia emarginata*: 1, male; 2, female; 9, apical whorls.—*Vancleaveia emarginata canadensis:* 3, male; 4, female; 5, immature; 10, apical whorls.—*Vancleaveia lacustris*: 6, male; 7, female; 8, immature; 11, apical whorls.—*Cincinnatia cincinnatiensis chicagoensis:* 12, type; 13, 14, paratypes; 15, immature. (Camera lucida drawings).

3). The genus has the center tooth of Potamopyrgus and the lateral tooth of Cincinnatia. *Canadensis* occurs more or less abundantly on the shore of Lake Michigan and is exactly like the form as it occurs in the type locality, Lake Kakiska, near mouth of Beaver River, west of Great Slav Lake, about latitude 61°. The variety is also found commonly in the Pleistocene deposits of Glacial Lake Chicago and in other Pleistocene deposits in Illinois. In the Chicago deposits, the variety may be observed in its changing variation from the river form, with almost closed umbilicus, to the widely umbilicated form of the Great Lake.

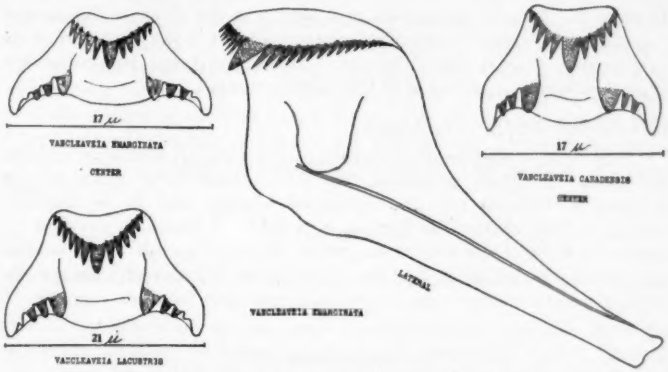

Fig. 3. Radula of Vancleavèia, central teeth and one lateral tooth.

Canadensis is to be considered a lake variety of *emarginata*, but it would seem advisable to separate the race called *lacustris* from Winnebago Lake as a species, the shell being much wider and having 2½ apical whorls coiled in the same plane while in *emarginata* and *canadensis* there are but 1½ whorls in this plane. The spire whorls in *lacustris* are separated by deep sutures, a feature not present in *emarginata*. The figures illustrate this difference (Fig. 2; 6-8, 11). The species of Vancleaveia may then be written:

Vancleaveia emarginata (Kuster). The river form with closed umbilicus (1, 2, 9).

Variety canadensis (F. C. Baker). Lake form with open umbilicus (3-5, 10).

Vancleaveia lacustris (F. C. Baker). Form with wide, flattened spire whorls (6-8, 10).

The lake forms, *canadensis* and *lacustris*, have a much higher center tooth than the river form, *emarginata*. The whole family of Amnicolidae is in need of revision, based on examination of genitalia and radula, and until such revision is made such groups as offer dif-

ferences in radula or genitalia must be considered as genera. When this has been done it may be advisable to reduce some genera to subgenera. See the Wisconsin Monograph, I, page 127 for a description of *lacustris*. It is to be observed, however, that the figure of the radula is incorrect and represents *Cincinnatia cincinnatiensis judayi* and not *lacustris* (see also that figures 40 and 55 have been transposed in the monograph).

Birgella subglobosa (Say)

This large amnicoloid occurs very rarely in the lake. It is like the typical lake form which occurs in the northern lakes of Wisconsin and Minnesota. *Birgella subglobosa* also occurs in the Chicago Pleistocene deposits from which it undoubtedly migrated into Lake Michigan or its predecessor, Glacial Lake Chicago. All of the fossil specimens are typical *subglobosa*, none are of the variety *isogona*.

Campeloma rufum (Haldeman)

The reddish species of Campeloma occurs in fair numbers in Lake Michigan. It differs somewhat from the species as it occurs in the streams of Illinois, but this difference appears not to be constant enough to differentiate the form as a variety. It shows, however, a response to Great Lake conditions, which in other groups has produced quite distinct variations. In the Pleistocene deposits of Chicago the change from the river type to the lake type may be seen.

PLEUROCERIDAE

Pleurocera acuta Rafinesque

The typical lake form of this species occurs more or less abundantly in the lake, and is like the typical form as it occurs in Lake Erie. It is very rare in the Chicago Pleistocene deposits appearing quite late in the history of Glacial Lake Chicago.

Goniobasis livenscens (Menke)

The long-spired form of this species, which is considered typical, the type coming from Lake Erie, is rare in Lake Michigan, though more common in the small lakes bordering the south shore of the lake. In the Chicago Pleistocene this species is very abundant in all lake stages from the Toleston stage to the end of the Lake Chicago stages.

Goniobasis livescens michiganensis F. C. Baker

The shorter, heavier form of livescens first observed in Lake Michigan on the Door County peninsula (see Wisconsin Monograph, I, p. 183) occurs abundantly on the shore of Lake Michigan near Chicago, and probably elsewhere in the southern part of the lake region. It does not occur, in its typical aspect, however, in the Chicago deposits, but in the later stages of Lake Chicago the *livescens* may be observed to be undergoing a change toward the shorter lake form.

Michiganensis appears to be the form of the wave-beaten shore, while typical *livescens* occurs more abundantly in small bays and the mouths of rivers flowing into the Great Lakes. In Lake St. Clair and the Detroit River the form is typical *livescens* and not *michiganensis*.

LYMNAEIDAE

Stagnicola woodruffi (F. C. Baker)

This Lymnaeid is one of the most abundant species in Lake Michigan, the shore from Michigan to Illinois sometimes being strewn with the bleached shells. There is little variation from the typical form and it appears to be one of the most distinct species of the genus. Curiously enough, it is very rare in the Chicago Pleistocene deposits, the few specimens thus far found having a longer spire and somewhat resembling some forms of *catascopium*. It is possible that *woodruffi* is a descendant of *catascopium*, but the latter species has not yet been found in fossil deposits in Illinois nor does it occur living in the rivers of the state. *Woodruffi* is the only lymnaeid living the Lake Michigan near Chicago.

PLANORBIDAE

Gyraulus arcticus ('Beck' Moller). See Wis. Mon., I, pl. 23, figs. 34-38.

A few specimens of this small species occur in the Lake Michigan material. *Arcticus* is related to *Gyraulus altissimus* (F. C. Baker), but differs in its rounder basal whorls, those of *altissimus* being much flattened and having a more 'reamed out' appearance. *Arcticus* is apparently the modern descendant of *altissimus*. The latter occurs more or less abundantly in the Chicago deposits and shows some indications of variation toward *arcticus*.

PHYSIDAE

Physella sayii (Tappan)

Lake Michigan shore from Millers, Ind., to Lake Forest, Ill. A form of this species occurs very abundantly along the entire south shore of Lake Michigan and extends up the west shore as far, at least, as Sturgeon Bay. It is smaller than typical *sayii*, as found in Ohio and in the smaller lakes of Wisconsin, and the spire is usually more dome-shaped and not as acute. Much the same form occurs in the later Chicago deposits. These lake forms evidently indicate a response to the rougher lake environment which has produced a smaller shell and a broader, more depressed spire. The Chicago Pleistocene material indicates a transition from long to short spire. As the range of variation in this species is very great it does not seem desirable to bestow a separate name on these short-spired Great Lake forms.

Physella integra billingsii (Heron)

A small Physella occurs on the Lake Michigan shore which appears referable to Heron's species, which the writer has considered a race of *integra* (see Wis. Mon., I, p. 463). It is always smaller than typical *integra*, has a wider whorl at the shoulder, the spire is less elevated and the aperture is much less ear-shaped. *Integra* occurs in the Chicago Pleistocene deposits and varies much toward both river and lake form. If we take the heavy, long-spired, ear-shaped shell designated by Haldeman as typical, then the smaller shell with more regular aperture is clearly separable as a lake race, which also inhabits the smaller lakes and river estuaries of the Great Lake region. These forms are certainly not typical *integra*, unless we choose to lump all ecological variations under that name, which would be quite undesirable. Curiously enough, this species was represented only by immature and very young specimens in the material obtained by Dr. Cahn at Division Street.

THE CAUSE AND SOME EFFECTS OF SOIL ACIDITY

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Since ancient times, soil acidity has been considered a factor in the production of crops, and it is generally recognized that this acid condition has an unfavorable influence upon soil fertility. It has long been known that lime has a beneficial influence upon cultivated lands, because of its ability to correct acidity and otherwise improve the condition of the soil. Hence, we have the saying by Hillgard (4), "A limestone country is a rich country."

Soil acidity in certain respects is not unlike many other forms of acidity. The definitions by Clark (2) apply equally well in the case of soil acids: "Acid still means sour, like vinegar. This common meaning preserves the ancient flavor of the word. An acid is any substance which is capable of supplying to its solution or to other substances, hydrogen ions bearing a positive electric charge. A base in any substance which is capable of supplying to its solution or to other substances the electronegative OH group."

The cause and nature of soil acidity have not been fully understood until recently and there has been considerable confusion as to its origin. At an earlier time, it was supposed that this acidity was due to acids originating from the organic matter that might be in the soil. This supposition was not well founded, as was pointed out by Hopkins (5) and others, because the acidity of upland well areated soils usually increased very markedly as the organic matter decreased, consequently, while some of the acidity might be due to organic acids, there are acid silicates which probably account for most of the acidity.

As soil science developed, there were evolved two outstanding theories regarding the cause and origin of soil acidity. One of these is known as the adsorption theory and the other the mineral acid theory. The justification for these two theories is discussed fully by Truog (11). Soil material presents an enormous surface and, hence, should exhibit an appreciable adsorptive phenomenon. The definition given by Holmes (7) is "that adsorption is a surface holding and depends largely, not wholly, on extent of surface."

The adsorption theory of soil acidity is based on the principle that the colloids of the soil have the power of selective adsorption for certain ions. Thus, the taking up of anion in preference to a cation or vice versa of a neutral salt was held to be the cause of the acid reaction of soils.

Truog (11) showed by experiments that when side reactions were eliminated, acid soils took up nearly chemical equivalent amounts of bases, thus indicating that soil acidity involved a chemical reaction which followed the laws of pure chemistry. However, adsorption is regarded as a physical phenomenon and maximum adsorption has no relation to chemical equivalents between adsorbent and adsorbed substance. The fact that the soil acidity reaction followed the stoichiometry laws of pure chemistry indicated that it was due to true acids in the soil and not selective adsorption of the colloids.

A more exact knowledge of soil acidity was arrived at when there was obtained a better understanding of the base exchange capacity of soils. This capacity of soils was demonstrated by Way (14) first in 1850, and the significance of this work seems to have been generally forgotten or overlooked until more recent years, when it was revived by Van Bemmelen (13), Gedroiz (3), Hissink (5), Kelley and Brown (8), Truog (12), and many others who worked on this phase of soil investigation.

The work of Kerr (9, 10) in which was used base exchange methods and an application of equilibrium equations to the results showing definitely that soil acidity involved a base exchange reaction which followed stoichiometric laws (the weight relationship that obtains when chemical changes take place) of pure chemistry. Kerr (10) also showed that alumino-silicic acids are the active inorganic compounds which function in the acidity of mineral soils. ,These alumino-silicic acids are in the solid phase of the clay or colloidal fraction of soils. Regarding colloids, Bancroft (1) states, "We now call a phase colloidal when it is sufficiently divided." Colloidal refers to the very finely divided portion of soils which contains the soil acidity or base exchange complex. Kerr (10) shows considerable evidence that indicates the formula H_2O $(Al_2O_3{-}6SiO_2)$:$8H_2O$ as the active inorganic compound which functions in acid mineral soils.

There are then two general phases of soil acidity. The solid phase composed of the alumino-silicic acids and humic acids and

the liquid phase or acids in the soil solution usually composed of sulphuric hydrochloric, nitric, carbonic and small amounts of many other acids. The acidity in the soil solution is infinitely small compared to that of the solid phase. There exists, however, an equilibrium between the acidity of the solid phase and that of the liquid phase of soils. A pH determination, which is the hydrogen ion concentration of the soil solution, represents in a degree the basis for determining the total acidity of the soil because of the equilibrium between the two phases.

The effects of soil acidity, which influences mainly plant growth, may be classified by the direct and indirect injury exerted on plants. Among some of the direct influences is that of too high a ratio of acids to bases in the soil solution which enter the plant and prove harmful to its growth. In an acid soil, the low supply of calcium is likely to be directly harmful to the plant. There is a possibility of a direct effect of acidity on plant roots providing the acidity goes as low as pH 4, which is unlikely.

The indirect influences of soil acidity are numerous. Acidity affects the availability of phosphorous, nitrogen and potassium in the order named. In an acid soil the phosphorous goes over to a more insoluble form and becomes less available to plants.

Toxic agents such as Al, Cu, Zn, Pb, B, and As, are likely to be more active under acid conditions.

Bacteria in the soil are dependent on the soil solution for certain minerals and if acidity removes the essential minerals the bacterial life suffers. This affects nitrogen fixing, symbiotic, nonsymbiotic nitrifiers and bacteria in general which flourish in soils.

Acidity influences the physical condition of soils. For example, calcium coagulates or flocculates colloidal material which improves the general physical makeup. If calcium is removed by acids, the colloidal material becomes deflocculated and the soil is compact and has an undesirable physical condition.

Some plant diseases are favored by an acid soil, however, potato scab flourishes on a soil rich in lime but does not do so well on an acid soil.

The competitive powers of different species of plants differ under acid conditions. An example is red sorrel (rumex acetosella) which flourishes on either an acid or non-acid soil, however, on a soil rich in lime, competing vegetation usually

crowds out red sorrel while on an acid soil, this plant often predominates.

Using soils from two Illinois experiment fields and considering the cause and nature of soil acidity and its influence on plant growth, there may be made a direct comparison of soil composition and its productive capacity. The comparison of composition is found in Table I.

TABLE I—COMPOSITION OF SOILS FROM TWO EXPERIMENT FIELDS.

Location of field	pH	Organic matter	Nitrogen	Phosphorous	Total bases milli-equiv.
		Per cent	Per cent	Per cent	
Hartsburg	6.1	5.04	0.252	0.064	3.80
Toledo	5.1	2.76	0.138	0.027	0.61

In Table I the two soils represented are normal, well drained farm lands, typical of certain areas of Illinois. The Hartsburg soil is classified as black clay loam, and the Toledo soil is gray silt loam on tight clay. Both are of the surface layer or A_1 horizon. The Hartsburg soil with the higher pH or more nearly neutral soil, also has a correspondingly higher percentage of organic matter, nitrogen phosphorous and milligram equivalents of total bases, (milligram equivalents indicate chemical equivalents expressed in milligrams per 100 grams of soil). The Toledo soil having a pH of 5.1 is ten times as acid as the Hartsburg soil with a pH of 6.1 and contains considerably less of the essential plant food elements as indicated by the data in Table I.

Taking next the productiveness of these two soils, there are the same wide differences when the crop yields are considered on the respective fields.

TABLE II—CROP YIELDS PER ACRE FROM TWO EXPERIMENT FIELDS.

Location of field.	Wheat	Corn	Oats	Legume hay
	Bushels	Bushels	Bushels	Pounds
Hartsburg	28.1	54.0	45.8	3,740
Toledo	7.8	17.0	13.8	420

In Table II is given a ten-year average crop yield, except hay eight years, for the two experiment fields. This data shows that

there is a positive correlation between the composition including acidity and the productivity of these two soils. On the very acid soil of the Toledo field the crop yields are much lower than on the less acid soil of the Hartsburg field. These two fields are located in near enough proximity to each other so that seasonal variations are of no great consequence. The very acid soil is less than one-third as productive as is the less acid soil. As soils become older, there is a loss of mineral elements and organic matter, soil acidity develops with all of its accompanying ills, and the productiveness of the land gradually declines.

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AN ABNORMALITY IN THE UROGENITAL SYSTEM OF NECTURUS

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During the course of the ordinary laboratory work in the Department of Zoology, University of Illinois, a specimen of *Necturus maculosus* Rafinesque was encountered which exhibited an interesting abnormality in the urogenital system. A description of the specimen, with an attempt to explain the anomaly on the basis of embryology, is offered here.

DESCRIPTION

The specimen was a sexually mature female, both ovaries being present and filled with eggs of various sizes. On the right side were present the elongated, white, convoluted oviduct opening into the anterior end of the body cavity at the funnel-shaped ostium tubae, and, the minute, straight, unpigmented ureter situated on the lateral border of the mesonephros. These ducts had the usual proportions and appeared essentially normal. An examination of the organs *in situ* failed to reveal the presence of an oviduct on the left side. Further search disclosed the presence of a thin, membranous, vesicle-like structure attached to the dorsal body wall in the anterior end of the body cavity. This occupied the same position as a normal ostium tubae. However, no opening could be made out. The left ureter, which normally is delicate and more or less translucent, was considerably enlarged and somewhat pigmented along its lateral border near the anterior extremity of the mesonephros. Although it was not tortuous it thus resembled in appearance its homologue in the male. The general appearance of the organs *in situ* is shown in figure 1.

Extending craniad from the anterior extremity of the mesonephros along the dorsal wall of the body cavity was a narrow, densely pigmented cord. This spread out fan-like and gradually disappeared in the mesentery attaching the above-mentioned vesicle-like structure to the dorsal body wall. To the naked eye this cord appeared to be an undoubted continuation of the ureter as is illustrated in figure 2. Microscopic sections were made in the

anterior region of the mesonephros in an attempt to determine this point. Unfortunately this procedure met with failure owing to the bad preservation of the tissue.

A similar pigmented cord is normally present in the male Necturus. It bears the same relation to the Wolffian duct and presents almost identically the same appearance as in this specimen. According to some authors, notably von Wittich ('53) and Owen ('66), it represents a continuation of the Wolffian duct. Or to express it in other words, it is a remnant of the pronephric duct which persists but has undergone atrophy as a result of the pronephros having lost its importance as an excretory organ. Kingsley ('07), at least, implies this, because he asks the question (page 9) "How far forward does it extend?" and follows up with the statement that "this portion in front of the testis is functionless." Most authors have been somewhat reticent regarding the significance of this cord. The more recent writers, however, are agreed that it represents the rudimentary Müllerian duct and not a continuation of the mesonephric duct or, in other words, the persistent pronephric duct. Balfour ('81), in describing the origin of the Wolffian and Müllerian ducts in Amphibians, claimed that the anterior portion of the Wolffian duct anterior to the mesonephros "undergoes a more or less complete atrophy." According to Chase ('23) the mesonephric duct in both sexes begins at the anterior end of the mesonephros as a continuation of the most anterior collecting tubule and extends posteriorly along its lateral border increasing in diameter slightly throughout its extent. He claims (page 470) that "in the male the Müllerian ducts are rudimentary structures indicated chiefly by a strip of black pigment cells which run longitudinally along the greater part of the lateral edge of the Wolffian duct, following its convolutions. Anterior to the kidney each Müllerian duct runs, covered by the peritoneum, along the dorsal wall of the body cavity just lateral to the posterior cardinal vein, appearing as a slender, cylindrical, densely pigmented cord of cells."

EMBRYOLOGICAL CONSIDERATIONS

Obviously we must look to the facts of embryology for an interpretation of the present anomaly. However, when we attempt to view the embryological aspects in order to apply them to this case we immediately run into difficulties, since authors are not in

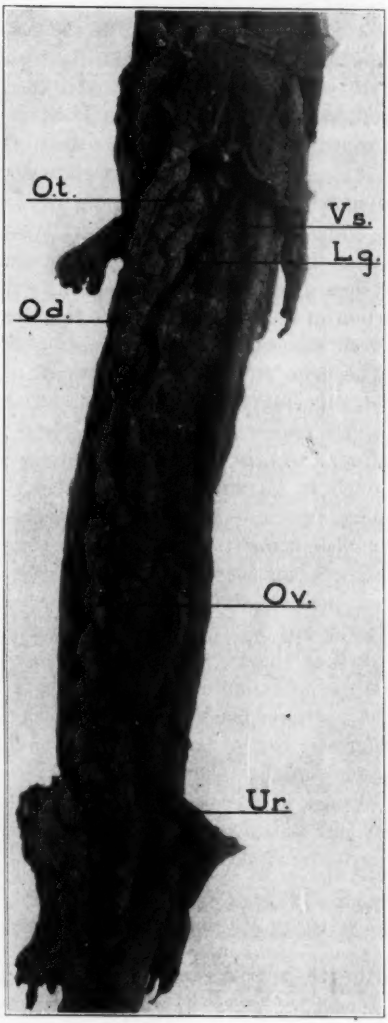

FIG. 1. Photograph of the abnormal specimen of Necturus, showing the appearance of the organs of the Urogenital system. Lg., left lung; Od., right oviduct; O.t., ostium tubae; Ov., ovaries; Ur., left ureter; Vs., Vesicle-like structure. The left lung was kept intact in order to preserve the pigmented cord shown in fig. 2.

FIG. 2. The Urogenital system on the left side, with the ovaries removed, showing the general appearance of the pigmented cord and its relation to the anterior extremity of the mesonephros and ureter. M.k., mesonephros; Ms., mesentery attaching the vesicle-like structure to the dorsal body wall; M. t., collecting tubule; P. c., pigmented cord; Ur., ureter; Vs., vesicle-like structure.

agreement as to the method of development of these structures in the Amphibia. As far as the writer is aware there is nothing in the literature bearing on the mode of formation of these structures in Necturus and no attempts have thus far been made to ascertain such. Any considerations, therefore, concerning the embryology of the structures in question in an attempt to account for the present abnormality are more or less hypothetical.

Authors have been almost unanimous in their opinions as to the relationship of the pronephros and mesonephros in the Amphibia. It is generally agreed that the pronephric duct arises from a longitudinal groove formed by an outpocketing of the somatopleure in the dorsal wall of the body cavity. This groove becomes converted into a canal by a constriction which commences near its anterior end and thence extends caudad. The anterior end remains in communication with the body cavity at 2, 3, or 4 places, depending upon the species, thus giving rise to the nephrostomes of the pronephros. The posterior end eventually acquires an opening into the cloaca. As soon as the pronephros loses its importance as an excretory organ and its functions are assumed by the mesonephros it undergoes atrophy. The pronephric duct, however, persists and becomes bodily converted into the mesonephric duct. This duct is then replaced by two ducts, the Wolffian (dorso-median) and Müllerian (ventro-lateral) ducts.

The origin of these two ducts has long been the subject of controversy. It is pretty generally conceded, however, that the Wolffian duct represents the original mesonephric duct. Balfour ('81) demonstrated that, whereas, in elasmobranchs the original mesonephric duct is represented by the Müllerian duct, in Amphibians it is represented by the Wolffian duct. The real difficulty therefore lies in determining the origin of the Müllerian duct especially as regards its relation to the Wolffian duct. It is sometimes described as developing in connection with, sometimes independently of the latter. According to one view the Müllerian duct is formed in Amphibians by a longitudinal splitting of the mesonephric duct from before backward as in the elasmobranchs. Fürbringer ('78) described the process in *Salamandra maculosa* as occurring by a progressive separation, from before backward, of a solid cord of cells from the ventral side of the mesonephric duct, the cord gradually acquiring a lumen. He claimed that the remaining portion of the mesonephric duct constitutes the Wolffian duct. Wilson ('94) maintained that in *Siredon pisciformis* the

Müllerian duct is formed by an evagination of the peritoneal epithelium in the region of the pronephros and that it extends backward opposite to and independent of the mesonephric duct. Gemmil ('97) and Hall ('04) both claimed that, whereas, the anterior portion of the Müllerian duct arises by an evagination of the peritoneal epithelium and extends caudad adjacent to the mesonephric duct with which it fuses for some distance and then grows backward free, a small portion of this backward growing duct takes cells from the mesonephric duct.

Another problem of equal significance and still subject of considerable dispute is the mode of formation of the ostium tubae. One view, which is taught in some text books, is that it represents one or the fusion of several pronephric nephrostomes. According to the account which at present receives the most general acceptance, it is formed by one or the coalescence of several evaginations of the peritoneal epithelium in the region of the pronephros but independent of the latter. This evagination is said to fuse secondarily with the cephalic end of the Müllerian duct and after acquiring an opening thus establishes communication with the body cavity.

It is evident that, in spite of the uncertainty in the interpretation of the origin of the Müllerian duct and its ostium tubae in the Amphibia, authors are agreed that the anlagen of the duct originates in the anterior region of the body cavity progressing caudad from this point, and that the ostium tubae develops independently of the Müllerian duct later fusing with it secondarily. Since recent authors have demonstrated that the Müllerian duct persists in both sexes in Amphibians, and, that as the female reaches sexual maturity it becomes dilated and convoluted, but remains thin and inconspicuous in the male, its rudiments being represented by a slender pigmented cord extending craniad from the anterior extremity of the mesonephros, the present anomaly, therefore, may be explained by assuming that it represents a persistent embryonic condition or the failure of the Müllerian duct to attain maturity. As to the significance of the vesicle-like structure in the region normally occupied by the ostium tubae, the suggestion is offered here that it represents a retarded condition of the peritoneal evagination, which, according to other authors, normally fuses with the cephalic end of the Müllerian duct and after establishing an opening furnishes the latter with an ostium tubae.

The abnormally large size of the ureter might possibly be associated with the failure of the Müllerian duct to reach maturity. However, this could not be determined in the light of our present knowledge of the method of development of these two ducts and their relation to each other in Necturus. The importance attached to the study of this abnormality lies not merely in the peculiarities presented by this particular specimen but rather in the fact that it brings us face to face with the need of more enlightment on the origin of the ducts of the Urogenital system in Necturus.

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NOTES ON THE DIGESTIVE AND REPRODUCTIVE SYSTEMS OF THE GERMAN COCKROACH*

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The digestive system of the German cockroach (*Blattella germanica* L.) is very simple in structure, presenting the typical insectan parts with little complexity or specialization. The reproductive system is also of a primitive type in the female, but in the adult male it presents a marked specialization of some of the parts, and a reduction of others.

DIGESTIVE SYSTEM

The digestive system (Fig. 1 and 2) is a tube extending the entire length of the insect, beginning at the base of the mouthparts, and ending at the anus, coiled upon itself once in the mid-abdominal region. It consists of an oesophagus, crop, proventriculus, mid-intestine, small and large intestines and rectum. The mid-intestine has an anterior ring of caeca, the enteric caeca, and the small intestine an anterior ring of fine tubules, the malphigian tubules. The salivary glands and their reservoirs lie beside the oesophagus and crop but are not appendages of the digestive tract.

The *oesophagus* and *crop* form a continuous, gradually widening sack, with no division separating them. This sack extends half the length of the body, reaching into the abdominal region. The crop when empty is deeply longitudinally furrowed, less so when gorged with food. The color is white or gray, depending on the food contained. When cleared in xylol the muscles give it a reticulate appearance. The wall of the crop (Fig. 4) consists of three layers, the muscular, epithelial and chitinous layers. The muscular layer comprises two sets of muscle fibres (*m*) running at right angles to each other, and forming a lattice work around the outside of the crop. The epithelium (*ep*) is made up of a single layer of low, cuboidal cells, which have relatively small nuclei. The epithelium secrets a thin chitinous lining (*cl*) which lines the crop. When the crop is empty the epithelium is thrown into small contorted folds, irrespective of the folds of muscle.

* Extract from a thesis submitted in partial fulfillment of the requirements for the degree of B.S.A. at the University of British Columbia, comprising work done in the Department of Zoology.

The crop joins bluntly with the *proventriculus*, or gizzard, which is the grinding organ of the digestive tract (Fig. 1, *p*). The gizzard is very short, joining the crop with a broad base and tapering to join the midintestine. It contains six teeth (Fig. 3), which divide the internal surface into six equal areas. The teeth are almost uniform in size and outline, and are dark brown in color. They fit up against the curved upper half of the gizzard, and have a broad, flat base, a thin, pointed tip, and a stout, down-curved beak jutting out two-thirds down the tooth. Between each tooth are eight chitinous lines, light yellow in color, granular in appearance, forming four spatulate loops, the loop being at the top (cephalad). Each tooth rests upon a thick membranous cushion, square from the face view, but with its corners rounded. From the base of each cushion a band of muscle runs down the part of the gizzard which extends into the mid-intestine.

The *mid-intestine* (Figs. 1 and 2, *mi*, and Fig. 5) forms one-half of the intestinal loop. It is almost uniform in thickness, tapering slightly where it joins the small intestine, and its external walls are of a reddish-ochreous color. The caeca (*ec*), which are white, are given off immediately after the junction with the gizzard. These are usually eight in number, forming an eccentric ring, the longer caeca to the inside, the shorter to the outside of the coelome. The two very short pairs point cephalad, but the two longer pairs rest against the mid-intestine, and point caudad. Occasionally a fifth pair of caeca are present, but if so they are merely bud-like protuberances beyond the smallest normal pair. According to Plateau (1874), the caeca excrete a slightly acid substance which emulsifies fats and converts albuminoids into peptones. From near the union of the mid-intestine and the proventriculus a membranous tube, the peritrophic membrane, is continuously secreted, which surrounds the incoming food like a curtain and prevents it coming into direct contact with the delicate epithelial layer (Imms, 1925; Comstock, 1926). This membrane has not been detected in these studies, although it doubtless occurs in this species. The outside muscular layer (*m*) of the mid-intestine is made up of two layers of muscle fibres at right angles to each other, appearing in histological sections as longitudinal, transverse or tangetial, depending upon the angle of the cut. In some slides a third series of muscle fibres appear, running tangentially across the other two. The epithelium (*ep*) consists of a row of slender columnar cells, which line the inner wall of the intestine.

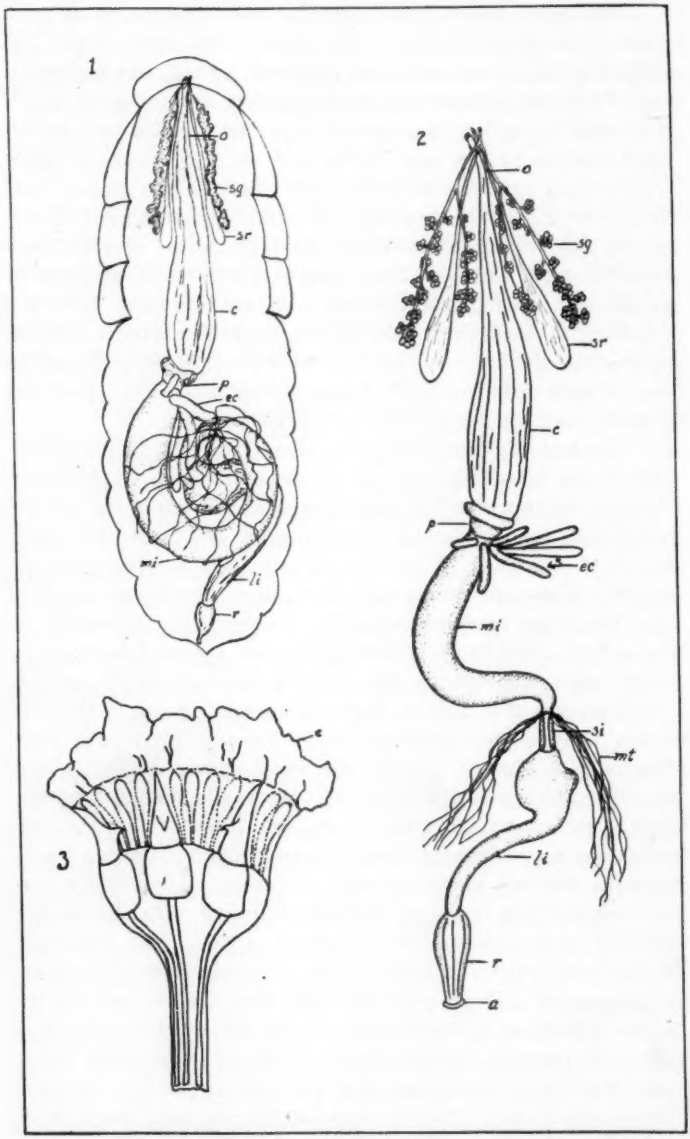

FIG. 1. Dorsal view of digestive tract and salivary glands, *in situ*.
FIG. 2. Dorsal view of digestive tract and salivary glands, extended.
FIG. 3. Inner wall of proventriculus.

These cells do not excrete a chitinous lining, so that it is in this region that most active digestion and absorption of food takes place. In secreting the digestive agencies, the cell forms a clear substance (ep^1) which forms like a drop in the swollen apex of the cell, then apparently bursts and discharges its contents into the interior of the stomach, nothing but a shrivelled cell-wall and nucleus remaining (ep^2). At their apices the epithelial cells bear a "striated hem" (*sh*) (Imms, 1925), which is thought by different authors either to be a series of minute canals or to consist of fine plasmic processes. The spent cells are continually replaced by new cells formed in the epithelial buds (*epb*), which are groups of regenerative cells scattered throughout the epithelium at the base of the cells.

The small intestine (Fig. 1 and 2, *sm*) is a short section of the digestive tract of small bore. It has a thick wall, and gives out at its junction with the mid-intestine the malphigian tubules. These arise in six clusters. They are long and thread-like, and twine throughout the abdominal visceral mass. According to Imms the histological structure of the small intestine of this species is quite similar to that of the rectum. The small intestine, together with the following length of the digestive tract, possesses an inner chitinous lining. The malphigian tubules (Fig. 9) are very simple in structure, consisting of flat, cuboidal epithelial cells surrounding the lumen.

The *large intestine*, or colon, is nearly as long as the crop. Where it joins with the small intestine, the colon is large and bulb like, posteriorly constricting to a regular tube about the thickness of the mid-intestine, and tapering to a small passage where it enters the rectum. The wall of the large intestine (Fig. 6) is composed of the typical three layers, muscular (*m*), epithelial (*ep*) and chitinous (*cl*). The inner muscular band is very thick, the outer one somewhat scattered and sparse. In the bulb-like upper portion of the colon the epithelium is thrown up into declevitous folds (Fig. 6), the cells of the folds being large and irregular, those between them being small and cuboidal, many of the latter giving rise to thread-like processes (*epp*). In the lower portion of the colon the ridges are lower, and the epithelium appears more evenly wave-like. The chitinous layer is thin and regular.

The rectum (Figs. 1 and 2, r) is small and urn-like in appearance, large at the top and small at the bottom. Six longitudinal

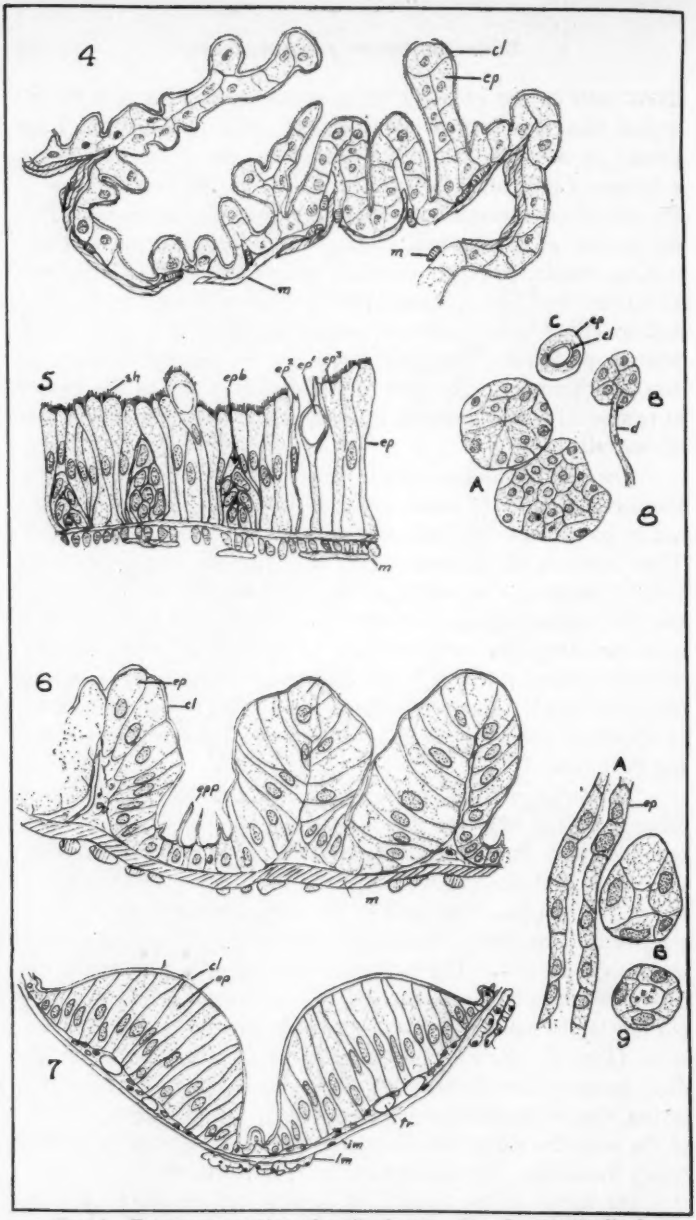

FIG. 4. Transverse section of wall of crop. FIG. 5. Longitudinal section of wall of mid-intestine. FIG. 6. Transverse section of wall of large intestine. FIG. 7. Transverse section of rectum. FIG. 8. Salivary glands: A, section of acini; B, section of acinus showing duct; C, transverse section of large duct. FIG. 9. Malphigian tubules: A, longitudinal section; B, transverse section.

dark bands, running its whole length, are visible on the exterior, the external indications of the internal epithelial bands. The wall of the rectum (Fig. 7) is composed of the same layers as the colon. The circular (inner) muscular band (*im*) forms a regular sheet around the tract. The longitudinal muscle fibres (*lm*) are congregated into six thick bands placed at the intervals between the epithelial folds. The epithelium (*ep*) is molded into six longitudinal, equal major folds. Between each of the large folds there is a minor fold one cell in width. The chitinous layer (*cl*) almost touches the basement membrane between each of the twelve folds. In the large folds the epithelial cells are slender and columnar, tallest in the middle, decreasing in height towards the edges. The nuclei are usually situated at about one-half the height of the cell, but occasionally occur at the base. The chitinous lining is thin and even, similar to that in other parts of the digestive tract.

SALIVARY GLANDS

The salivary glands are not appendages of the digestive tract, but so intimate are they with the latter that no description is complete without their consideration.

The salivary glands and their reservoirs (Fig. 1, *sr* and *sg*) lie longitudinally appressed to the crop, reaching half its length. The main duct of both the glands and reservoirs are separate in the thoracic region, uniting in the head near the outlet of the salivary glands on the hypopharynx. The glands are in two halves, one on each side of the crop, each half again dividing, the inner branch being slightly the smaller. The acini, or groups of actively secreting cells, are clustered at the end of small branches from the main ducts, and when extended (Fig. 2, *sg*) resemble long bunches of grapes. The two main ducts of each half of the gland unite below the last acini, and the main ducts thus formed unite above the oesophagus just within the thorax. The two reservoirs (*sr*) lie one on each side of the oesophagus, are slightly longer than the salivary glands, and are partly hidden by them in their natural position.

The acini of the salivary gland (Fig. 8) have no lumen. The duct of each acinus (*d*) is composed of revolute, thin epithelial cells, similar to those lining tracheae. The larger ducts are composed of thick, spongy-looking cells, which secrete the chitinous lining of the duct. The cells of the acini are typically cone-shaped, the apices of the cells meeting in the centre, with the nucleus

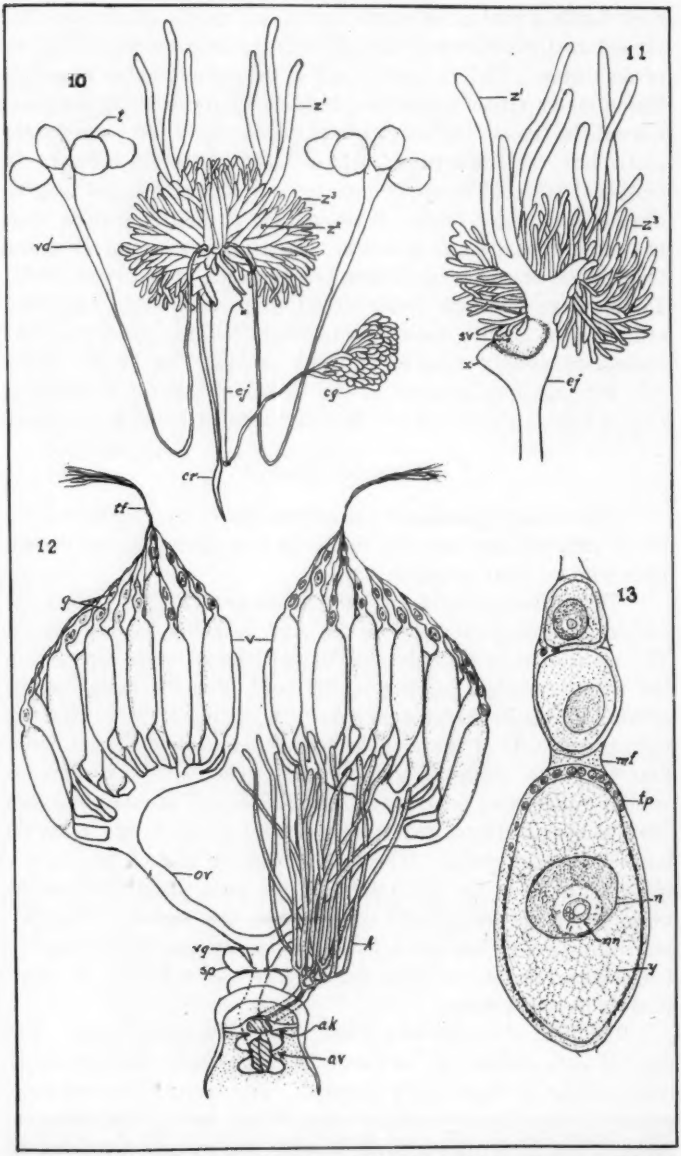

FIG. 10. Dorsal view of male reproductive organs. FIG. 11. Ventral view of accessory gland of male. FIG. 12. Dorsal view of female reproductive organs. FIG. 13. Longitudinal section through a young ovarian follicle.

situated towards the circumference of the acinus. These cells stain readily with haematoxylin and appear purple and constitute the large majority of the cells. A small number of cells situated on the circumference of the acinus are flatter than these and do not appear to have any contact with the centre of the acinus or the duct. They do not stain with haematoxylin, but stain readily with eosin, so they appear red in the ordinary counterstained sections. Thus there appears to be a striking similarity between these purple and red staining cells, both in staining quality and in position, to the chief and parietal cells, respectively, of the human gastric glands (Lewis and Stohr, 1913).

REPRODUCTIVE SYSTEM IN THE FEMALE

The female reproductive organs (Fig. 12) consist of the typical paired ovaries and oviducts, a vagina, two spermathecae, a colleterial gland, and the genital armature. Each *ovary* consists of numerous ovarian follicles attached to the oviduct by a stalk. The follicles each contain a large pre-natal egg forming the vitellarium (*v*), which is long, cylindrical and rounded at the ends, surmounted by two small paranatal eggs, one very small, the two forming the germarium (*g*), the follicle then tapering into a thin terminal (*tf*). The filaments of each ovary unite and are securely anchored by numerous small tracheal threads (*tr*) proceeding from the third abdominal spiracle. One tracheole follows each filament and descends to the egg. The number of follicles making up each ovary varies very greatly, but judging from several individuals examined just before egg laying, the usual number is about twenty-four. The two ovaries of the same individual have not always the same number, sometimes with a difference as great as five. In each ovary near maturity, there are usually three to six follicles which appear under-developed.

In a young ovary (Fig. 13) the three eggs do not show such a great difference in size as in an older one (Fig. 12). They all have, near the centre, a very large nucleus (*n*), which possesses a distinct nucler membrane. Within it is a clear area in the middle of which is a large, deeply-staining nucleolus (*nn*) containing several pellucid droplets. Around the nucleus, and occupying the greater part of the egg, is the yolk (*y*), and surrounding the egg is the developing follicular epithelium (*fp*). At this early stage the follicular epithelium is a more or less primitive plasmic body with nuclei only in the apical portion. The follicular mem-

brane (*m*) is very fine, and continuous throughout the entire length of the follicle. In ovaries which are almost mature the two paranatal eggs are relatively minute and the basal egg very large. The yolk in the latter (Fig. 14, *y*) is distinctly cellular and very greatly increased in proportion to the size of the nucleus. The follicular epithelium (*fp*) is a distinct cellular envelope around the egg, the cells flattened, each cell with a distinct nucleus. At the apex of the egg there is a cap of columnar epithelial cells (*gc*) whose shape and position, together with the fact that in the younger ovaries the nuclei in the epithelium are only at the apex, strongly suggest that this is the generative centre for the follicular epithelium.

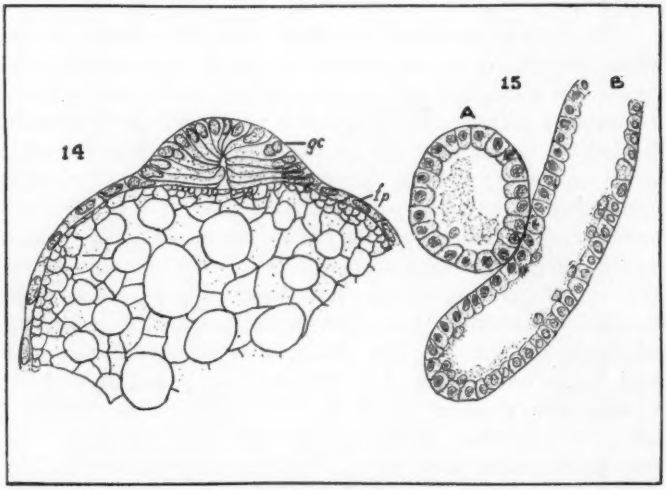

FIG. 14. Longitudinal section through apex of almost mature vitellarium.
FIG. 15. Colleterial gland: A, transverse section; B, longitudinal section.

From the cluster-like ovaries the two *oviducts* (*ov*) pass back and unite in a broad Y to form the *vagina* (*vg*). The oviducts are long and sinuate, the vagina is short and straight. No egg-calyxes have been found even in mature specimens. The vagina passes through a hard, cushion-like structure (*q*) which is attached to the genital plate (*w*), and opens through a valve (*av*) situated in the middle of the latter. Just before it enters the genital armature the vagina bears two ovoids sacs (*sp*) which are con-

sidered to be *spermathecae.* They are situated on the dorsum of the vagina one on each side of the meson. Miall and Denny (1886) record only one spermatheca in *Blatta orientalis* L.

The *colleterial gland* (*k*) is composed of a large number of long, thin tubes resulting from frequent abrupt dichotomous divisions of the base or duct. The duct opens through an aperture immediately above that of the vagina. The tubes (Fig. 15) consist of a wall of cuboidal epithelial cells resting upon a thin outside membrane, which is thick and gelatinous around the duct. This large gland secretes the substance which forms the wall of the ootheca.

REPRODUCTIVE SYSTEM IN THE MALE

The male adult reproductive system (Figs. 10 and 11) exhibits a very marked reduction of the testes and specialization of the accessory glands.

The *testis* (*t*) is composed of four or five round follicles arranged in a flat cluster. In this species they appear quite fully developed although small in the adult, but Miall and Denny (1886) state that in *Blatta orientalis* they are fully formed only in the large nymphs and are degenerate and small in the adults. The *vas deferens* (*vd*) is a long, thin tube running from the testis to the ejaculatory duct, making in its journey a long narrow loop into the posterior part of the body. It is almost bulbous at the testis, narrowing to a fairly wide tube, then narrowing again to form a much thinner one, and entering the ejaculatory duct at the base of the tubules of the accessory glands. The *ejaculatory duct* (*ej*) is a stout tube tapering towards the posterior end and at its anterior end giving rise to or serving as the seat of various structures. The most conspicuous of these is a large ball of tubules (z, z^2, z^3), comprising the *accessory gland,* the function of which is unknown. Seen from the dorsal aspect (Fig. 10) this mass shows three distinct kinds of tubules: (1) a small number (eight to twelve) of long, thick tubules (z) which are much larger than the others and extend forward much beyond them, (2) a large number of shorter, yet fairly thick tubules (z^2) occupying most of the dorsal aspect, and (3) a greater number of thin tubules (z^3) arising behind those of (2) and extending slightly beyond them in an almost even circle. From the ventral aspect (Fig. 11) the long tubules are seen to be prolongations of the ejaculatory duct, and to these the term "ectadenia" of Escherich (Imms) fits

well. The two series of short tubules evidently arise from the dorsal surface of the ejaculatory duct at the point where the vasa deferentia enter it, and to these the term "mesadenia," also of Escherich, is applied. On the right side of the ejaculatory duct is a conical evagination (*x*), and on the ventral side, adjacent to it but at a slightly higher level is an irregular bulb-like process (*sv*). This may represent the *seminal vesicle.* Just before the ejaculatory duct enters the mass of genital armature it is joined by the duct of another gland (*cg*) made up of closely appressed but distinct tubules. Miall and Denny (1886) consider it under the name "conglobate gland." The function of this gland, also, is unknown. Attached to the ejaculatory duct by transparent muscle is a long, thin, chitinous rod (*r*), a little longer than the duct, and surmounted at the posterior end by a sickle-like head. This rod is, no doubt, a part of the genital armature.

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LIST OF ABBREVIATIONS USED IN PLATES

a — anus
ak — opening of colleterial gland
av — opening of vagina
c — crop
cg — conglobate gland
ci — chitinous lining
cr — chitinous rod
d — duct
ec — enteric caeca
ej — ejaculatory duct
ep — epithelium
ep¹ — discharging epithelial cell
ep² — burst epithelial cell
ep³ — normally shaped epithelial cell
epb — epithelial bud
epp — epithelial process
fp — follicular epithelium
gc — generative cap
im — inner muscle
k — colleterial gland
li — large intestine
lm — longitudinal muscle
m — muscle
mi — mid intestine
mf — follicular membrane
mt — malphigian tubules
n — nucleus
nn — nucleolus
o — oesophagus
ov — oviduct
p — proventriculus
q — "cushion" of female genitalia
r — rectum
sg — salivary glands
sh — striated hem
si — small intestine
sp — spermatheca
sr — salivary reservoir
sv — seminal vesicle (?)
t — testis
tf — terminal filaments
tr — tracheoles
v — vitellarium
vd — vas deferens
vg — vagina
w — genital plate
x — conical evagination of ejaculatory duct
y — yolk
z¹ — ectadenia
z² — mesadenia
z³ — mesdaenia

CHARACTERISTICS OF GRAPE VARIETIES UNDER TEST AT THE ILLINOIS AGRICULTURAL EXPERIMENT STATION

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During the last few years, with the increasing interest in small fruit culture in Illinois, there has come about a considerable demand on the part of both the amateur and the commercial grower for more detailed information from the Agricultural Experiment Station as to the varietal characteristics of the small fruits which can be grown successfully in the state.

In response to this demand a beginning has been made with the grape. The information in the accompanying table has been compiled from varietal studies carried on in the Station vineyard and cold storage plant at the Horticultural Field Laboratory, University of Illinois, Urbana, from 1921 to 1929.

Since local conditions influence the blooming and ripening dates, as well as other characteristics of the varieties, it should be stated that the latitude of Urbana is 40° 7′. The altitude is approximately 755 feet above sea level. The average rainfall is 36.89 inches. The average annual maximum temperature is 98.1 degrees F., while the average minimum is –11.1 degrees. There is an average growing season of 173 days.

The vineyard is situated on the eastern slope of a recessional moraine, characteristic of the early Wisconsin glaciation. The soil is brown silt loam of morainal type, merging into a black clay spot at the base of the slope.

The data as given in the table are based upon a nine-year average for most varieties. The letters *R, G,* and *B,* under color, signify red, green, and black, respectively, occasionally being further defined by *P* for purple and *Y* for yellow. The letters *H* and *M* refer to home and market. The numerals one to five designate varietal characteristics on a sliding scale of excellence. For example, the figure one signifies that the variety so characterized bears a very small cluster and berry, is lacking in hardiness and vigor, is a very poor yielder, is very early in blossoming and ripening, very poor in eating quality, and keeps only a few days in storage. The figure five denotes the other extreme.

Variety.	Color.	Size of cluster.	Size of berry.	Hardiness.	Vigor.	Productivity.	Cross-pollination needed.	Earliness in blooming.	Earliness in ripening.	Eating quality.	Keeping quality.	Recommended for home or market.	Uses.	Remarks.
Agawam	P-R	3	4	3	5	3	------	3	4	5	5	H-M	Dessert	Aromatic flavor. Subject to mildew.
August Giant	B	3	5	4	4	3	x	3	3	5	4	------	Dessert	Subject to mildew.
Bacchus	B	1	2	5	5	4	x	1	5	1	5	H	Juice	Subject to leaf hopper and phylloxera.
Barry	B	4	5	5	5	3	x	3	4	5	4	H	Dessert	A variety for the amateur.
Berckmans	R	2	2	5	4	3	------	2	4	3	4	------	Dessert	Resembles Delaware.
Beta	B	1	2	5	5	4	------	1	2	1	4	------	Culinary	Subject to root worm and phylloxera.
Black Malvoise	B	5	5	0	4	4	------	2	3	3	5	------	Dessert	Needs winter protection and special sprays.
Brighton	R	4	4	5	4	5	x	3	3	5	5	H-M	Dessert	Subject to leaf hopper.
Caco	R	2	4	5	4	3	------	3	4	5	4	H	Dessert	A Concord-Catawba cross.
Campbell	B	5	5	4	2	2	------	3	2	4	3	------	Dessert	Subject to leaf hopper.
Carman	B	3	3	5	4	2	------	5	4	2	3	------	Culinary	Of no particular value.
Catawba	P-R	4	4	4	3	3	------	4	4	5	5	------	Juice Dessert	Subject to mildew and leaf hopper.
Champion	B	4	4	5	5	4	------	2	1	1	2	------	Culinary	An inferior variety.
Chasselees Rose	R	3	2	0	3	2	------	5	3	3	5	------	Dessert	Needs winter protection and special sprays.
Clinton	B	2	2	5	5	3	------	1	5	2	5	------	Juice	Subject to leaf hopper and mildew.
Colerain	G	3	3	4	2	1	------	3	3	5	3	------	Dessert	A Concord seedling. Subject to root worm.
Concord	B	4	4	5	5	5	------	3	3	3	3	H-M	Dessert Juice	Standard mid-season variety. Subject to root worm.
Delaware	R	2	2	5	3	4	------	4	3	5	5	H-M	Juice Dessert	Standard by which grape quality is gauged. Subject to mildew.
Diamond	G	3	3	5	3	4	------	4	2	5	3	H	Dessert	Subject to leaf hopper and black rot. For northern sections.
Dracut Amber	R	3	4	5	3	2	------	3	2	1	2	------	Culinary	Fruit has no merit. Thick skin and foxy flavor.
Dutchess	Y-G	3	2	4	3	2	------	5	5	5	4	------	Dessert	Not adapted to all soils.
Early Victor	P-B	2	3	4	4	3	------	3	2	3	2	------	Dessert	Subject to leaf hopper and black rot.
Eaton	B	4	5	4	3	2	------	3	3	2	2	------	Dessert	Inferior to Concord, its parent.
Eclipse	B	3	3	3	2	3	x	3	1	3	2	------	Dessert	Injured by root worm and phylloxera.
Elvira	G-Y	2	3	5	3	5	------	2	4	1	3	------	Juice	Injured by root worm and phylloxera.
Empire State	Y-G	3	3	4	5	3	------	5	4	5	4	H	Dessert	Subject to leaf hopper and mildew.
Etta	G	2	2	5	3	4	------	3	4	2	3	------	Juice	A seedling of Elvira which it resembles.
Eumelan	B	2	3	3	4	3	x	4	4	5	5	------	Juice	Subject to mildew.
Gaertner	R	4	4	4	4	2	x	3	4	5	5	------	Dessert	Not adapted to all soils. Subject to leaf hopper and mildew
Geyer	G	3	3	4	3	3	------	3	3	3	2	------	Dessert	Needs further test.
Goethe	R	3	5	4	4	3	------	3	5	3	5	------	Dessert	Subject to leaf hopper.
Goff	R	4	4	5	3	4	------	5	3	5	5	H	Dessert	Fruit superior, subject to leaf hopper.
Green Early	G	3	2	4	4	3	------	4	2	3	2	------	Dessert	Injured by root worm and phylloxera.

Variety.	Color.	Size of cluster.	Size of berry.	Hardiness.	Vigor.	Productivity.	Cross-pollination needed.	Earliness in blooming.	Earliness in ripening.	Eating quality.	Keeping quality.	Recommended for home or market.	Uses.	Remarks.
Greins Golden	Y-G	2	4	4	4	4	x	3	4	2	2	------	Juice	Skin cracks easily.
Hartford	B	3	3	4	4	3	------	2	1	1	2	------	Culinary	Fruit characteristics poor.
Herbemont	B	2	3	0	5	4	------	5	5	3	2	------	Dessert	Needs winter protection. Killed 1919-20.
Herbert	B	4	5	5	5	4	x	3	3	4	5	H-M	Dessert	A superior variety.
Hubbard	B	4	4	5	5	3	x	3	3	4	5	------	Dessert	Needs further test.
Iona	R	3	3	4	4	4	------	5	5	4	3	H	Dessert	Fruit superior. Vine not adapted to all soils.
Isabella	B	3	3	3	4	3	------	2	4	4	2	------	Culinary	Subject to leaf hopper, black rot, and mildew.
Ives	B	2	3	4	3	2	------	3	3	1	3	------	Juice	Fruit inferior. Subject to leaf hopper and phylloxera.
Janesville	B	3	4	5	3	4	------	1	2	1	4	------	Culinary	Subject to mildew, leaf hopper, and phylloxera.
King	B	5	5	5	4	2	------	4	3	3	2	------	Dessert	May be a bud-sport of Concord. Subject to mildew.
Lady Washington	Y-G	4	3	4	3	2	------	4	4	4	3	------	Dessert	An exhibition variety. Subject to mildew.
Lindley	R	2	4	4	4	3	x	4	3	5	4	H	Dessert	Aromatic flavor. Subject to leaf hopper and mildew.
Lucile	R	4	4	5	4	5	------	3	3	2	3	------	Culinary	Vine better than fruit.
Lutie	R	3	4	5	4	4	------	2	1	3	2	------	Culinary	Develops foxy flavor in storage.
Marion	B	2	2	5	2	3	x	2	4	2	3	------	Juice	Subject to leaf hopper.
Martha	G	2	3	4	4	3	------	3	3	4	3	------	Dessert	A Concord seedling, now little grown.
Moore	B	4	4	4	3	3	------	3	1	3	2	H-M	Dessert	Standard early. Subject to mildew and leaf hopper.
Moyer	R	2	3	4	4	3	x	3	1	5	4	H	Dessert	"An early Delaware for northern regions." Subject to leaf hopper and mildew.
Niagara	Y-G	5	4	3	5	4	------	3	3	4	5	H-M	Dessert	Subject to leaf hopper, black rot, and winter injury.
Noah	Y-G	3	3	3	4	4	------	2	4	2	2	------	Juice	Fruit cracks and shatters. Subject to mildew.
Norton	B	2	2	5	5	4	------	5	4	2	4	------	Juice	Subject to leaf hopper, mildew, and black rot. Injured by root worm.
Ontario	G	2	3	5	4	3	------	4	1	4	4	H-M	Dessert	Promising new variety.
Pocklington	Y-G	4	4	4	3	3	------	3	4	4	4	------	Dessert	Subject to leaf hopper.
Regal	R	2	4	4	4	4	------	3	4	4	3	------	Dessert	Subject to leaf hopper.
Salem	R	2	4	5	4	3	x	3	4	5	4	------	Dessert	Subject to mildew, injured by root worm.
Ulster	R	3	4	4	3	4	------	2	4	4	3	------	Dessert	Subject to leaf hopper. Injured by root worm and phylloxera.
Urbana	R	4	4	4	3	4	------	4	4	5	5	H	Dessert	Fruit with thick skin. Superior quality.
Vergennes	R	3	4	4	3	4	x	3	4	4	5	H	Dessert	Subject to leaf hopper.
Wilder	B	4	5	5	4	4	x	3	3	4	4	------	Dessert	Subject to leaf hopper.
Winchell	G	3	3	5	3	4	------	3	2	4	3	------	Dessert	Subject to leaf hopper.
Woodruff	R	3	4	5	3	4	------	3	4	2	2	------	Culinary	Fruit shatters. Subject to leaf hopper.
Worden	B	4	5	5	3	5	------	3	2	5	2	H	Dessert	Skin cracks easily. Subject to leaf hopper.
Wyoming	R	2	3	5	4	4	x	3	2	2	4	------	Culinary	Subject to leaf hopper.

ILLINOIS MOSSES

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Two early collectors, John Wolf and Elihu Hall, published in 1878 a list of mosses based largely upon collections made in Fulton and Menard counties, listing 50 genera and 153 species.

In 1887, Frederick Brendel listed 87 mosses from the area covered by his "Flora Peoriana." For many years there was little interest shown in this group of plants. Recently, however, they have attracted some attention from ecologists.

As a beginning in the study of the Bryophytes of Illinois, the information that is available from herbariums and from literature has been assembled in this paper. Many of the mosses of the two early lists are not easily recognized today by the names then in use, so these mosses have been included in this list.

The Herbarium of the University of Illinois contains a number of collections, the two most extensive are those of Frederick Brendel and E. J. Hill. The former includes the Peoria mosses, and the latter the mosses collected from the counties of Indiana and Illinois which immediately border Lake Michigan. The collections altogether are far from being state-wide. Little work has been done in northwestern Illinois and still less in the southern half of the state with the exception of Randolph, Johnston, and Union counties. Amateur collectors would find many counties new and interesting fields for work.

The moss collections of Wolf and Hall are not at present available for study. The Wolf scientific collections were given to the High School of Canton, Illinois, and were never prepared for display or study. The Hall plant collection is in the Field Museum, but not yet incorporated in the Herbarium.

In the following list specimens designated as "U of I" are in the University Herbarium, as also are those designated as "Hill" except a very few which are in the Field Museum. Other mosses from the Field Museum are credited either to the collector or to the collection.

Synonymous names are in italics. Localities are indicated by names of counties, usually followed by names of towns.

The arrangement of families and genera follows that of the second edition of Engler and Prantl, but the names of the genera and species are, for the most part, those in use in Grout's "Mosses with a Handlens and Microscope" and in Vol. III, Part 1, of "Moss Flora of North America."

SOURCES

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1884 Manual of Mosses of North America, by Leo Lequereux and Thomas P. James.

1887 Flora Peoriana, by Frederick Brendel.

1920 Ecological Succession of Mosses, by Aravilla Meek Taylor, Bot. Gaz., Vol. 69, pp. 449-491.

1920 Appearance of Mosses in Ecological Habitats, by Aravilla Meek Taylor. The Bryologist, Vol. 23, pp. 81-84.

FISSIDENTALES

FISSIDENTACEAE

Fissidens adiantoides (L.) Hedw.
Peoria: (Brendel)
Fulton, Menard, Kane: (Wolf, Hall)
Fissidens bryoides (L.) Hedw.
Cook: Glenwood (U of I)
McHenry: Ringwood (Hill)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Fissidens bryoides var. inconstans
Locality not mentioned (Hill)
Capsules: October
Fissidens cristatus Wils.
Fissidens decipiens Denot.
Cook: Deep River; Glenwood (Hill)
Lake: Waukegan; Lake Bluff; Lake Forest (Hill)
Carroll: (Taylor)
Fissidens grandifrons Brid.
LaSalle: Deer Park; Starved Rock (Hill)

Fissidens exiguus Sull.
Cook: Thornton (Hill)
Will: Crete; Troy Twp. (Hill)
Capsules: June, November
Fissidens inconstans Sch.
Fissidens synoicus Sull.
Cook: Glenwood (Hill)
Will: Lockport (Hill)
Capsules: April, June
Fissidens incurvus Schwaegr.
Carroll: Savanna (U of I)
Capsules: July
Fissidens incurvus var. minutulum Aust.
Fissidens minutulum Sull.
Cook: Lemont (Hill)
Will: Mokena; Lockport (Hill)
Carroll: Savanna (Hill)
Kankakee: Kankakee (Hill)
Peoria: Princeville (Hill)
Fulton, Menard: (Wolf, Hall)
Capsules: June, July, August, November
Fissidens obtusifolius Wils.
Fulton: (Wolf) (U of I)
Fissidens subbasilaris Hedw.
Lake: Lake Bluff (Hill)
Marion: (U of I)
Peoria: (Brendel)
Fulton, Menard, McHenry: (Wolf, Hall)
Capsules: November
Fissidens taxifolius (L.) Hedw.
Bryum taxifolius Hedw.
Cook: Glencoe (Hill)
Fulton: Canton (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Octodiceras debilis (Schwaeg.) n. c.
Conomitrium julianum Mont., *Fontinalis juliana* Savi.
Cook: Thornton; Sag Bridge (Hill)
Will: Troy Twp. (Hill)
Fulton, Menard: (Wolf, Hall)
Octodiceras hallianum (S. and L.) J. and S.
Conomitrium hallianum S. and Lesq., *Fissidens hallianum* Mitt.
Menard: (Wolf, Hall)

ARCHIDIACEAE

Archidium ohioense Sch.
Menard: Athens (Hall) (Wolf, Hall)

BRYALES

DITRICACEAE

Pleuridium alternifolium (Dicks. Kaulf.) Raben.
Phascum alternifolium Brid.
Cook: Chicago Heights (Hill)
DuPage: Downer's Grove (Hill)
Will: Lockport (Hill)
Sangamon: Springfield (Bebb)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Pleuridium subulatum (L.) Rabenh.
Phascum subulatum Huds.
Peoria: Princeville (U of I)
Ditrichum pallidum (Schreb.) Hampe
Leptotrichum pallidum Hampe, *Trichostomum pallidum* Hedw.
Cook: Glencoe; Glenwood; Barrington; Berwyn (Hill)
Lake: Highland Park (Hill)
Champaign: Mahomet (U of I)
Wabash: Mt. Carmel (U of I)
Menard: Athens (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Ditrichum tortile (Schrad.) Hampe
Leptotrichum tortile Muell., *Trichostomum tortile* Schrad.
Cook: Glenwood (Hill)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Ditrichum tortile var. purillum Hedw.
Cook: Chicago Heights (U of I)
Ceratodon purpureus (L.) Brid.
Cook: Englewood; Riverside; Grand Crossing (U of I)
Will: Lockport (Hill)
Lake: Lake Forest; Crystal Lake (Harper)
Stark: Wady Petra (U of I)
Champaign: Urbana (U of I)
Henderson: Oquawka (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)

DICRANACEAE

Trematodon longicollis Rich.
Union, Johnson: (Wolf, Hall)
Bruchia beyrichiana Hampe
Locality not mentioned (Wolf, Hall) (Lesq. and J.)
Bruchia curviseta Lesq. and J.
Stark: (U of I)

Bruchia donnelli Aust.
Locality not mentioned (Hall)
Bruchia flexuosa Schwaeger.
Fulton: (Wolf, Hall)
Locality not mentioned (Rau and Hersey)
Bruchia hallii Aust.
Fulton: (U of I)
Bruchia sullivantii Aust.
Lake: Chicago Heights (U of I)
Dicranella heteromalla (L.) Sch.
Dicranum heteromallum Hedw.
Cook: Beverly Hills; Glenwood; W. Pullman; Maywood (Hill)
Ogle: Liberty Hill; Oregon (Hill)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Dicranella rufescens (Dicks.) Sch.
Fulton; Menard (Wolf, Hall)
Dicranella varia (Hedw.) Sch.
Dicranum varium Hedw.
Cook: Thatcher's Park; Glencoe (Hill)
Will: Mokena (Hill)
Lake: Lake Bluff; Lake Forest (Hill)
Marion: (Bebb)
Henderson: Oquawka (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Dicranella varia var. tenella
Cook: Glenwood (Hill)
Lake: Lake Bluff (Hill)
Campylopus leanus Sull.
Fulton, Menard: (Wolf, Hall)
Dicranum bonjeani DeNot.
Dicranum palustre LaPyl
McHenry: Wauconda (Hill)
Locality not mentioned: (Wolf, Hall)
Dicranum flagellare Hedw.
Cook: Niles; Glencoe (Hill)
Fulton, Menard, Johnson: (Wolf, Hall)
Dicranum scoparium (L.) Hedw.
Cook: (Taylor)
Lake: Highland Park (Hill)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Dicranum scoparium var. pallidum
Cook: Highland Park (Hill)
Peoria: (U of I)
Dicranum scoparium var. condensatum
Menard: (Wolf, Hall)

Dicranum undulatum Turner
Lake: Lake Bluff (Hill)
Fulton: (U of I)
Fulton, Menard: (Wolf, Hall)

LEUCOBRYACEAE

Leucobryum albidum (Brid.) Lindb.
Leucobryum minus Hampe; Leucobryum glaucum var. minus Hampe
Fulton: (U of I)
Johnson: (Wolf, Hall)
Leucobryum glaucum (L.) Sch.
Leucobryum vulgare Hampe
Cook: Glencoe (Hill)
Union: (U of I)
Peoria: Mossville (Brendel) (U of I)
Fulton, Menard: (Wolf, Hall)

ENCALYPTACEAE

Encalypta ciliata (Hedw.) Hoffm.
Will: Lockport (U of I)
Ogle: (Wolf, Hall)
Encalypta procera Bruch.
Will: (U of I)

POTTIACEAE (TORTULACEAE)

Astomum crispum (Hedw.) Hampe
Systegium crispum
Fulton: (Wolf, Hall)
Astomum nitidulum Sch.
Phascum nitidulum Sch., *Systegium nitidulum* Jaegr.
Cook: Riverside (Hill)
Will: Mokena; Crete; Lockport (Hill)
Fulton: (Wolf, Hall)
Astomum nitidulum var. pygmaeum Lesq.
Cook: Riverside
Will: Mokena (U of I)
Astomum sullivantii Sch.
Phascum sullivantii Sull., *Systegium sullivantii* Jaegr.
Will: Mokena; Crete (Hill)
Fulton, Menard: (Wolf, Hall)
Weisia viridula (L.) Hedw.
Champaign: Urbana (U of I)
Will: Mokena (U of I)
Weisia viridula var. gymnostomoides Muell.
LaSalle: Deer Park (U of I)

Weisia wolfii Lesq. and J.
Fulton: Canton (Lesq. and J., Wolf)
Gymnostomum calcarium Nees and Hornsch.
Cook: Lemont; Sag Bridge (Hill)
Will: Lockport (Hill)
Gymnostomum curvirostre (Ehr.) Hedw.
Hymenostylium curvirostre (Ehr.) Lindb.,
Cook: Lemont (Hill)
Kankakee: Rock Creek (Hill)
LaSalle: Deer Park (U of I)
Capsules: August
Gymnostomum rupestre Swaegr.
Cook: (Taylor)
Fulton: (U of I)
Tortella caespitosa (Schwaegr.) Limpr.
Barbula caespitosa Schwaegr.
Cook: near Colheur (Hill)
Lake: Lake Forest (Hill)
Fulton, Menard, S. Illinois: (Wolf, Hall) (U of I)
Didymodon rubellus (Hoffm.) B. and S.
Cook: Sag Bridge (Hill)
Fulton (Wolf, Hall)
Didymodon tophaeus (Brid.) Jur.
Trichostomum tophaeum Brid.
Cook: Sag Bridge (Hill)
Locality not mentioned (Wolf, Hall)
Capsules: October
Barbula fallax Hedw.
Barbula acuimnata Hedw.
Cook: Glencoe (Hill)
Lake: Lake Forest (Hill)
LaSaile: Deer Park, Starved Rock (Hill)
Fulton: (Wolf)
Capsules: July
Barbula rigida Schultz
Tortula stellata Lindb.
Menard (Wolf, Hall)
Barbula subulata Brid.
Tortula subulata Hedw.
Locality not mentioned (Wolf, Hall)
Barbula unguiculata (Huds.) Hedw.
Cook: Glenwood, Riverside, Lemont, LaGrange (Hill)
Lake: Lockport (Hill)
Henderson: Oquawka (U of I)
Peoria: (Brendel)
Menard (Wolf, Hall)
Barbula unguiculata var. apiculata
Will: Joliet (Hill)
Randolph: Bremen (Hill)

Barbula vinealis Braum
Menard: (Hall)
Aloina ericaecolia (Neck.) Lindb.
Barbula ambigua B. and S.
Acaulon floerkeanum Muell.
Phascum floerkeanum W. and M., *Microbryum floerkeanum* Sch.
Locality not mentioned (Lesq. and James, Hall)
Acaulon muticum Schreb.
Sphaerangium muticum Sch.
Fulton: (Wolf, Hall)
Acaulon schimperianum Sull.
Phascum schimperianum Sull., *Sphaerangium schimperianum* Lesq. and J.
Menard: Athens (Lesq. and J.)
Acaulon triquetrum (Spruce) C. Muel.
Sphaerangium triquetrum Sch.
Menard: (Wolf, Hall)
Acaulon wolfii James
Fulton: (Wolf)
Phascum cuspidatum (Schreb.) Hedw.
Will: Mokena (Hill)
Sangamon: Springfield (Bebb)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Desmatodon arenaceous S. and L.
Cook: Sag Bridge (Hill)
Desmatodon obtusifolius Sch.
Desmatodon flavicans B. and S.
Ogle: Oregon (Hill)
Peoria: (Brendel)
Fulton: (Wolf, Hall)
Capsules: July
Desmatodon porteri James
Cook: Sag Bridge (Hill)
Will: Lockport (Hill)
Kankakee: Altorf (Hill)
Fulton: Canton (U of I) (Wolf)
Capsules: June, July, August
Pterygoneurum subsessile (Brid.) Jur.
Pharomitrium subsessile (Brid.) Sch.
Pottia subsessile B. and S.
Menard: (Wolf, Hall)
Pterygoneurum exigium Aust.
Pharomitrium exigium Aust.
Pottia exigua Aust.
Menard: (Wolf, Hall)
Tortula mucronifolia Schwaegr.
Lake: Lake Forest (Harper)

Tortula papillosa (Muell.) Wills.
Barbula papillosa Wils.
Menard: (Hall)
Tortula rigida Schultz
Tortula stellata Lindb., *Barbula rigida* Hedw.
Menard: (Hall)

GRIMMIACEAE

Ptychomitrium drummondii Sull.
Grimmia drummondii Hook and Wils.
South Illinois (Wolf, Hall)
Grimmia apocarpa (L.) Hedw.
Schistidium aprocarpa B. and S.
Cook: (Taylor)
Carroll: (Taylor)
Rock Island: Port Byron (Harper)
Peoria: (U of I)
Menard: (Wolf, Hall)
Grimmia conferta Funck
Schistidium confertum B. and S.
Lake: Lake Zurick (Hill)
Will: (Hill)
Rock Island: Port Byron (Harper)
Peoria: (Brendel)
South Illinois (Wolf, Hall)
Grimmia conferta var. obtusifolia Sch.
Cook: Barrington; Sag Bridge; Riverside (Hill)
Will: Rock Run; Lockport; Joliet (Hill)
Lake: Lake Zurich (Hill)
Grimmia ovata W. and M.
South Illinois (Wolf, Hall)

DISCELIACEAE

Discelium incarnata Schwaegr
Discelium nudum Brid.
Fulton: (Wolf, Hall) (Lesq. and J.)

EPHEMERACEAE

Ephemerum cohaerens (Hedw.) Hampe
Phascum cohaerens Hedw.
Cook: Riverside (Hill)

Ephemerum crassinervium Schwaegr.
Phascum crassinervium Schwaegr.
Will: Mokena (U of I)
Fulton: (U of I)
Fulton, Menard: (Wolf, Hall)

FUNARIACEAE

Aphanorhegma serratum Sull.
Fulton, Menard (Wolf, Hall)
Capsules: July
Physcomitrella patens (Hedw.) B. and S.
Phascum patens Hedw.
Will: Mokena (Hill)
Physcomitrium acuminatum B. and S.
Gymnostomum acuminatum Schliech.
Cook: Lemont; Chicago Heights (Hill)
DuPage: Naperville (Hill)
Will: Lockport (Hill)
Locality not mentioned (Lesq. and J.)
Capsules: April, May, June
Physcomitrium immersum Sull.
Gymnostomum immersum Sull.
Cook: Niles; Beverly Hills (Hill)
Locality not mentioned (Wolf, Hall) (Rau and Hersey)
Physcomitrium pyriforme B. and S.
Gymnostomum pyriforme Hedw. .
Cook: Lemont; Lyons (Hill)
Will: Lockport; Troy Twp. (Hill)
Kankakee: Kankakee (Hill)
Stark: Wady Petra (Hill)
Peoria: (Brendel)
Physcomitrium turbinatum Michx.
Phascum strangulatum Kindb.
Cook: Maywood; Calumet (Hill) (U of I)
Champaign: Mahomet (U of I)
Henderson: Oquawka (U of I)
Stark: Wady Petra (U of I)
Will: Joliet (Hill)
Peoria: (Brendel)
Capsules: May, June, July
Funaria americana Lindb.
Cook: Lemont (Hill)
Will: Lockport (Hill)
Capsules: April, May, August
Funaria flavicans Mx.
Stark: (U of I)
Menard: (Wolf, Hall)
Capsules: June

Funaria hygrometrica (L.) Sibth.
Cook: Lemont; Jackson Park, Chicago; S. Chicago (Hill) (Taylor)
Will: Joliet (Hill)
Henderson: Oquawka (U of I)
Stark: (U of I)
Champaign: Urbana (U of I)
Kankakee: Kankakee (U of I)
Peoria: (Brendel) (U of I)
Fulton, Menard: (Wolf, Hall)
Capsules: June

Funaria microstoma B. and S.
Menard: (Wolf, Hall)
Locality not mentioned (Lesq. and J.)

GEORGIACEAE

Georgia pellucida (L.) Hedw.
Tetraphis pellucida Raben.
Cook: Glencoe (Hill)
Lake: Lake Forest (Hill)
Ogle: Oregon
Menard: (Wolf, Hall)
Capsules: May

BRYACEAE

Webera lescuriana (Sull.) Jaegr.
Bryum lescurianum Sull.
Fulton: (U. of I.)

Webera nutans Hedw.
Pohlia nutans Lindb.
Cook: Englewood; Riverside; Thornton; Glenwood; Western Springs; Willow Springs; Glencoe (Hill)
Lake:
McHenry: Wauconda (Hill)
Fulton, Menard: (Wolf, Hall)
Capsules: April, May, June

Mniobryum albicans (Wahlenb.) Limpr.
Mniobryum wahlenbergii W. and M. *Bryum wahlenbergii* W. and M.
Cook: Glencoe (Hill)
Lake: Lake Forest; Lake Bluff (Hill)
Ogle: Oregon (Hill)
Fulton, Menard: (Wolf, Hall)

Leptobryum pyriforme (L.) Wils.
Bryum pyriforme Hedw.
Rock Island: Port Byron (Harper)
Locality not mentioned (Hall) (Vasey)
Bryum argenteum (L.) Hedw.
Cook: Lyons; Glencoe (Hill)
Carroll: Savanna (Hill)
Kankakee: Kankakee (Hill)
Champaign: Urbana (U of I)
Henderson: Oquawka (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Capsules: May, July, September, November
Bryum argenteum var. lanatum
Rock Island: Port Byron (Harper)
Bryum atropurpureum Wahl.
Fulton, Menard: (Wolf, Hall)
Bryum bimum Schreb.
Cook: Englewood; Wolf Lake (Hill)
Will: Joliet (Hill)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Capsules: June
Bryum caespiticium L.
Cook: Englewood; Auburn Park; W. Pullman (Hill)
Will: Lockport (Hill)
Lake: Lake Forest; Lake Bluff (Hill)
DuPage: Naperville (Hill)
Henry: Geneseo (Harper)
Rock Island: Port Byron (Harper)
McHenry: Crystal Lake (Harper)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Capsules: March, April, May
Bryum cirratum Hoff. and Heinsh.
Cook: River Grove (Hill)
Lake: North Chicago (Hill)
Capsules: May, November
Bryum intermedium Brid.
Cook: Western Springs; Lemont; Barrington (Hill) (U of I)
Will: Lockport (Hill)
LaSalle: Deer Park (Hill)
DuPage: Naperville (Umbach)
Kankakee: Kankakee (Hill)
Stark: Wady Petra (U of I)
Fulton, Menard: (Wolf, Hall)
Capsules: May, June, August

Bryum obconicum Hornch.
Menard: (Wolf, Hall)
Bryum pendulum (Sch.) Hornsh.
Bryum cernum Hedw.
Cook: Lemont (Hill)
Henry: Geneseo (Harper)
Rock Island: Port Byron (Harper)
Fulton, Menard: (Wolf, Hall)
Bryum uliginosum B. and S.
Champaign: Mahomet (U of I)
Peoria: (Brendel)
Fulton: (Wolf, Hall)
Capsules: July
Rhodobryum roseum (Weis.) Limpr.
Bryum roseum Schreb.
Cook: Crete (Hill)
McHenry: Ringwood (Vasey)
Peoria: (Brendel)
Fulton, Menard, Kane: (Wolf, Hall)

MNIACEAE

Mnium affine Bland.
Cook: South Chicago (Hill)
Champaign: (U of I)
Kankakee: Kankakee (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Capsules: May
Mnium cuspidatum Hedw.
Cook: Englewood; Barrington; Glenwood; Beverly Hill; Evanston; Glencoe (Hill)
Lake: Lake Forest; Lake Bluff (Hill)
Kankakee: Kankakee (Hill)
Champaign: Mahomet; Urbana (U of I)
Woodford: Springbay (U of I)
Henderson: Oquawka (U of I)
Rock Island: Port Byron (Harper)
Marion: (Bebb)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Mnium marginatum (Dicks.) P. Beau.
Mnium serratum Schrad.
Lake: Lake Forest; Waukegan (Hill)
Menard: (Wolf, Hall)
Capsules: May, June
Mnium medium B. and S.
Lake: Lake Forest; Waukegan (Hill)

Mnium punctatum (L.) Hedw.
Menard: (Wolf, Hall)
Mnium rostratum (Schrad.) Schwaegr.
Champaign: Mahomet (U of I)
Lake: Waukegan (Hill)
Rock Island: Port Byron (Harper)
Capsules: May
Mnium stellare (Reich.) Hedw.
Menard: (Wolf, Hall)

AULACOMNIACEAE

Aulacomnium heterostichum (Hedw.) B. and S.
Lake: Waukegan; Lake Forest; Lake Bluff (Hill) (Harper)
Ogle: Liberty Hill; Oregon (Hill) (Bebb)
Champaign: Urbana (U of I)
Marion: (Bebb)
Hancock: Augusta (Meade)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Aulacomnium palustre Schwaegr.
Cook: Thornton; W. Pullman; Willow Springs; Berwyn; (Hill) (Calkins)
Lake: Wauconda (Hill)
Capsules: May, June
Aulacomnium palustre var. polycephalum B. and S.
Cook: Thornton (Hill)

MEESIACEAE

Meesia longiseta Hedw.
Lake: Highland Park (Hill)

BARTRAMIACEAE

Bartramia pomiformis Hedw.
Cook: Highland Park (Hill) (Taylor)
Lake: Lake Forest; Lake Bluff
Champaign: (U of I)
LaSalle: Starved Rock (U of I)
Henderson: Oquawka (U of I)
Rock Island: Port Byron (Harper)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Capsules: May
Bartramia pomiformis var. crispa Sch.
Lake: (Hill)
Capsules: May, July

Bartramia radicalis Beauv.
Menard: (Wolf, Hall)
Philonotis fontana (L.) Brid.
Bartramia fontana Brid.
Lake: Lake Bluff
Champaign: (U of I)
Schuyler: (Meade)
Menard: (Wolf, Hall)
Philonotis muhlenbergii (Schwaegr.) Brid.
Philonotis marchia Sull.
Lake: Lake Bluff (Hill)
Fulton: (Wolf, Hall)

TIMMIACEAE

Timmia megapolitana Hedw.
Cook: Glenwood; Lemont (U of I)
Lake: Lake Forest (U of I)
Winnabago: (U of I)
Henderson: Oquawka (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)

PTYCHOMITRACEAE

Ptychomitrium drummondii Sull.
Grimmia drummondii Hook and Wils.
Pulaski: (U of I)
Capsules: August

ORTHOTRICACEAE

Orthotrichum anomalum Hedw.
Will: Lockport (Hill)
Capsules: April, June
Orthotrichum fallax Sch.
Orthotrichum schimperi Ham.
Cook: Glenwood (U of I)
Orthotrichum fallax var. truncatulum Aust.
Locality not mentioned: (Lesq. and J.) (Rau and Hervey)
Orthotrichum lescurii Aust.
Orthotrichum cupulatum var. minus Sull.
Cook: Barrington (U of I)
Will: Lockport, Rock River, Troy Twp. (Hill)
Orthotrichum ohioense S. and L.
Orthotrichum canadense B. and S.
Fulton: (Wolf, Hall)

Orthotrichum strangulatum Beau.
Orthotrichum porteri Aust.
Cook: Glenwood; Lemont (Hill)
Will: Lockport; Joliet (Hill)
LaSalle: Deer Park (U of I)
Stark: (Hill)
Rock Island: Port Byron (Harper)
Marion: (Bebb)
McHenry: Ringwood (Vasey)
Peoria: (Brendel)
Capsules: May
Ulota crispa var. crispulum
Ulota crispula Bruch., *Orthotrichum crispulum* Bruch.
Cook: Chicago (Vasey)
Fulton, Menard: (Wolf, Hall)
Drummondia clavellata Hook.
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)

FONTINALACEAE

Fontinalis biformis Sull.
Marion: (Hall)
Fulton: (Wolf, Hall)

Fontinalis dalecarlica B. and S.
Carroll: Havanna (Vasey)
Fulton: (U. of I) (Wolf, Hall)

Fontinalis filiformis S. and L.
Fulton, Mason: (Wolf, Hall)

Fontinalis umbachii Chardot
Cook: Romeo (Hill)
Will: Lockport (Hill)

Dichelyma capillaceum (Dill.) B. and S.
Fulton: (Wolf, Hall)

CLIMACIACEAE

Climacium americanum Brid.
Cook: (Taylor)
Carroll: (Taylor)
Lake: Lake Forest; Lake Bluff (Hill)
Champaign: Mahomet (U of I)
Henderson: Oquawka (U of I)
Rock Island: Port Byron (Harper)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)

HEDWEGIACEAE

Hedwegia ciliata Ehr.
Hedwegia albicans (Web.) Lindb.
Cook: Barrington (Hill)
Lake: Lake Bluff; Lake Forest (Hill)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Hedwigia ciliata var. viridis
Cook: Barrington; Lemont (Hill) (U of I)

LEUCODONTACEAE

Leucodon julaceus (Hedw.) Sull.
Champaign: Urbana (U of I)
Peoria: (Brendel)
Fulton, Menard: S. Illinois (Wolf, Hall)
Forsstroemia ohioensis (Sull.) Lindb.
Leptodon ohioensis Sull.
Pulaski: (Wolf, Hall)
Forsstroemia trichomitria (Hedw.) Lindb.
Leptodon trichomitrium Mohr., *Forsstroemia var. immersus* Sull.
Locality not mentioned: (Hall)

NECKERACEAE

Neckera pennata (L.) Hedw.
Fulton: (U of I)
Porotrichum alleghaniense (C. M.) Grout
Thamnion alleghaniense B. and S., *Hypnum alleghaniense*
Fulton: (U of I)

THELIACEAE

Thelia asperella (Hedw.) Sull.
Cook: Near Morgan Park; Winnetka; Thornton (Hill)
Lake: Lake Bluff
Thelia hirtella Sull.
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Thelia lescurii Sull.
Fulton: (Wolf, Hall)

FABRONIACEAE

Fabronia gymnostoma Sull.
Fulton, Menard (Wolf, Hall)
Locality not mentioned (Rau and Hervey)
Fabronia octoblepharis (Schleich.) Schwaegr.
Menard: Athens (Lesq. and J.)
Fabronia wrightii Sulli.
Menard: Athens (Hall) (Lesq. and J.)

Anacamptodon splachnoides (Froel.) Brid.
Fabronia splachnoides (Froel.) Brid.
Fulton, Menard: (Wolf, Hall) (U of I)
Clasmatodon parvulus Hampe
Fulton: (Wolf, Hall)

LESKEACEAE

Fabroleskea austinii Sull.
Leskea austini Sull.
Cook: Crete (Hall)
Lake: Lake Villa (Hall)
Fulton, Menard: (Wolf, Hall) (U of I)
Leskea denticulata Sull.
Locality not mentioned: (Wolf, Hall)
Leskea gracilescens Hedw.
Cook: Lemont; Thornton; Western Springs (Hill)
Lake: Lake Villa (Hill)
Will: Crete; Homer; Lockport (Hill)
Capsules: July, August
Leskea obscura Hedw.
Cook: Thornton; Thatcher's Park; Berwyn; Western Springs; Glenwood (Hill)
Lake: Lake Zurich (Hill)
Champaign: Mahomet; Urbana (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Leskea polycarpa Ehr.
Cook: Western Springs; Riverside (Hill)
Will: Joliet (Hill)
Stark: Wady Petra (U of I)
Champaign: Urbana; Mahomet (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Leskea vitriculosus (L.) H. and T.
Carroll: (Taylor)
Pterigynandrum filiforme (Timm.) Hedw.
Neckera filiforme Muel.
Menard: Athens (Hall)

THUIDIACEAE

Anomodon attenuatus (Schreb.) Hueb.
Cook: Thornton; Glenwood (Hill)
Will: Crete; Homer (Hill)
Lake: Lake Forest; Lake Bluff (Hill)
Champaign: Urbana (U of I)
Marion: (Bebb)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)

Anomodon minor (P. Beau.) Fuern.
Anomodon obtusifolius B. and S.
Cook: Lemont; Evanston (Hill)
Will: Lockport (Hill)
Champaign: Urbana (U of I)
Henderson: Oquawka (U of I)
Marion: (Bebb)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)

Anomodon rostratus (Hedw.) Sch.
Cook: Evanston; Lemont (Hill)
Will: Lockport; Joliet (Hill)
Lake: Lake Bluff (Hill)
Champaign: Urbana (Hill)
Peoria: (Brendel)
Fulton, Menard: S. Illinois (Wolf, Hall)

Anomodon tristis (Cesati) Sull.
Leskea tristis Cesati
Peoria: (Brendel) (U of I)
Fulton, Menard: (Wolf, Hall)

Thuidium delicatulum (L.) Hedw.
Hypnum delicatulum Lindb.
Cook: (Taylor)
Lake: Wauconda (Hill)
Henderson: Oquawka (Hill)
Union: (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Capsules: August

Thuidium elodioides R. and C.
Lake: Wauconda (Hill)
Capsules: August

Thuidium microphyllum (Sw.) Best
Hypnum gracile B. and S., *Haplocladium microphyllum* (Sw.) Brath.
Cook: Thatcher's Park (U of I)
Lake: Ft. Sheridan (U of I)
Ogle: Oregon (U of I)
McHenry: Ringwood (Vasey)
Kane: Elgin (Vasey)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Capsules: August

Thuidium minutulum (Hedw.) B. and S.
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)

Thuidium recognitum (Hedw.) Lindb.
Hypnum recognitum Hedw.
Cook: Glenwood; Highland Park (Hill) (U of I)
Lake: Lake Bluff; Lake Forest (Hill)
Champaign: Mahomet; Urbana (U of I)
McHenry: Near Fox Lake (U of I)
Capsules: June, July, August
Thuidium scitum (Beau.) Aust.
Hypnum scitum Beau., *Rauia scitum* Aust.
Fulton, Menard: (Wolf, Hall) (U of I)
Thuidium virginianum (Brid.) Lindb.
Champaign: Urbana (U of I)

AMBLYSTEGIACEAE

Cratoneuron filicinum (L) Roth.
Amblystegium filicinum L.
Lake: Lake Bluff (Hill)
Will: Troy Twp. (Hill)
Capsules: June
Campylium chrysophyllum (Brid.) Bryhn.
Hypnum chrysophyllum Brid.,*Amblystegium chrysophyllum* DeNot.
Lake: Highland Park, Lake Bluff (Hill)
Will: Joliet (Hill)
Fulton: (Wolf)
Capsules: July, November
Campylium hispidulum (Brid.) Mitt.
Hypnum hispidulum Brid., *Amblystegium hispidulum* Kindb.
Cook: Englewood; Morgan Park; River Forest (Hill)
Lake: Highland Park; Lake Forest (Hill)
Champaign: Urbana (U of I)
McLean: Bloomington (U of I)
Menard: Athens (Hall)
Capsules: May
Campylium stellatum (Schreb.) Bryhn.
Hypnum stellatum Schreb.
Lake: Waukegan (Hill)
Campylium polygomum (Sch.) Bryhn.
Hypnum polygomum Wils.
Locality not mentioned (Hall)

AMBLYSTEGIACEAE

Amblystegium fluviatile B. and S.
Hypnum fluviatile Swartz, *Hygroamblystegium fluviatile* Loesh.
Cook: Sag Bridge (Hill)
Will: Rock Run (Hill)
Amblystegium irriguum (Wils.) B. and S.
Cook: Lemont (Hill)
Will: Troy Twp.; Joliet (Hill)

Amblystegium juratzkanum Sch.
Cook: Glenwood; Grand Crossing; Glencoe (Hill)
LaSalle: Deer Park (Hill)
Capsules: May, June, July

Amblystegium kochii B. and S.
Cook: W. Pulman; Berwyn (Hill) (Calkins)
Lake: Lake Forest (Hill)
Will: New Lenox (Hill)
Capsules: May, June, July

Amblystegium noterophilum (Sull.) Warnst.
Cook: Lemont; Berwyn (Hill) (Calkins)
Will: Joliet; Troy Twp.; Sag Bridge (Hill)
Capsules: June

Amblystegium orthocladon (Beau.) Jaeger
Hypnum orthocladon Beau., *Hypnum serpens* var. *orthocladon* Aust.
Cook: Willow Springs; Lemont; (Taylor) (Hill)
Lake: Cuba (Hill)
Will: Lockport (Hill)
Carroll: Savanna (Hill)
Rock Island: Port Byron (Harper)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)

Amblystegium radicale (Beau.) Mitt.
Hypnum radicale Beau.
Cook: Willow Springs; Hyde Park; Chicago Heights; Thornton (Hill)
Lake: Lake Bluff; Lake Forest (Harper)
Rock Island: Port Byron (Harper)

Amblystegium riparium (L.) B. and S.
Hypnum riparium L.
Cook: Grand Crossing; Romeo (Hill)
Will: Troy Twp. (Hill)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)

Amblystegium riparium var. abbreviatum
Cook: Summit; Lemont (Hill)
Lake: Wauconda (Hill)
Champaign: Urbana (U of I)
Capsules: June, July, August

Amblystegium riparium var. cariosum
Locality not mentioned: (Wolf, Hall)

Amblystegium riparium var. flaccidum
Cook: Grand Crossing (Hill)

Amblystegium riparium var. fluitans
Cook: Grand Crossing; Wildwood; Romeo (Hill)
Will: Joliet; Lockport (Hill)
Lake: Cedar Lake; Lake Villa (Hill)

Amblystegium serpens (L.) B. and S.
Hypnum serpens L.
Cook: Lemont; Englewood; Thatcher's Park; Romeo (Hill)
Lake: Chicago Heights (U of I)
Ogle: Oregon (Hill)
Henderson: Oquawka (U of I)
Champaign: Urbana (U of I)
Menard: Athens (Hall)
Rock Island: Port Byron (Harper)
Peoria: Princeville (U of I) (Brendel)
Amblystegium serpens var. radicale
Fulton, Menard: (Wolf, Hall)
Amblystegium subtile B. and S.
Hypnum subtile Hoff.
Cook: Willow Springs; Chicago Heights (Hill)
Amblystegium varium (Hedw.) Lindb.
Cook: Hyde Park; Grand Crossing; Willow Springs; Chicago Heights; Thornton; Wildwood; Glenwood; Lemont; Berwyn (Hill)
Will: New Lenox; Crete; Lockport (Hill)
Lake: Lake Forest; Waukegan (Hill)
Champaign: Urbana, Mahomet (U of I)
Carroll: Savanna (Hill)
Ogle: Oregon (Hill)
Rock Island: Port Byron (Harper)
Amblystegiella conferva (Schwaegr.) n. c.
Hypnum confervoides Brid.
Ogle: Liberty Hill; Oregon (Hill)
Amblystegiella adnata (Hedw.) Nichols
Hypnum adnatum Hedw., *Homomallium adnatum* (Hedw.) B.
Cook: Evanston (Hill)
Will: Joliet (Hill)
Kankakee: Kankakee (Hill)
Henry: Geneseo (Harper)
Rock Island: Port Byron (Harper)
Adams: Quincy (Harper)
Peoria: (Brendel)
Capsules: June
Drepanocladus aduncus (Hedw.) Warnst.
Harpidium aduncum Hedw., *Hypnum aduncus* Hedw.
Tazewell: (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Drepanocladus aduncus var. gracilescens Sch.
Cook: Lemont; Lyons (Hill) (U of I)
Lake: Lake Bluff; N. Chicago (Hill)
Will: Joliet (Hill)
Fulton: Canton (U of I)
Capsules: June

Drepanocladus aduncus var. Kneiffii Sch.
Lake: Wauconda (Hill)
Will: Joliet (Hill)
Drepanocladus aduncus var. attenuatus
Lake: Fox Lake (Hill)
Drepanocladus exannulatus (Gruebel) Warns.
Hypnum exannulatus B. and S., *Amblystegium exannulatus* Denot.
Lake: Lake Villa (Hill)
Drepanocladus fluitans (L.) Warnst.
Hypnum fluitans L., *Amblystegium fluitans* DeNot. var. *plumosus*
Cook: Palos Park (Hill)
Lake: Ft. Sheridan
Drepanocladus uncinatus (Hedw.) Warnst.
Cook: Palos Twp. (Hill)
Will: Joliet (Hill)
Calliergon cuspidatum (L.) Kindb.
Lake: Lake Villa; Wauconda; Irving Lake (Hill)

BRACHYTHECIACEAE

Camptothecium lutescens (Huds.) B. and S.
Hypnum lutescens Huds.
LaSalle: Deer Park (U of I)
Peoria: (U of I)
Camptothecium nitens (Schreb.) n. c.
Hypnum nitens Schreb.
Lake: Wauconda (Hill)
Homalotheciella subcapillata (Hedw.) Card.
Homalothecium subcapillatum B. and S.
Fulton, Menard: (Wolf, Hall)
Chamberlainia acuminatum (Hedw.) n. c.
Brachythecium acuminatum (Hedw.) Kindb.
Cook: Beverley Hills; Barrington; Lemont (Hill)
Lake: Lake Bluff (Hill)
Champaign: Urbana (U of I)
Marion: (Bebb)
Henderson: Oquawka
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Capsules: February, May, November
Chamberlainia acuminatum var. rupincula (S. and Lesq.)
Cook: Berwyn (Hill)
Will: Lockport; Joliet
Lake: Lake Bluff
Henderson: Oquawka (U of I)
Brachythecium acutum (Mitt.) Sull.
Hypnum acutum Mitt.
Will: Paterson's Quarry; Joliet (Hill)

Brachythecium collinum (Schleich.)
Hypnum collinum Schleich.
Locality not mentioned: (Wolf, Hall)
Brachythecium oxycladon (Brid.) Jaegr.
Hypnum oxycladon Brid., *Brachythecium laetum* Brid.
Cook: Glenwood; Glencoe; Chicago Heights (Hill)
Lake: Lake Forest; Lake Bluff; Lake Villa (Hill)
Will: Mokena; Lockport (U of I)
Henderson: Oquawka (U of I)
Rock Island: Port Byron (Harper)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Capsules: April, May, July, October, November
Brachythecium rivulare B. and S.
Hypnum rivulare B. and S.
LaSalle: Starved Rock (Hill)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Brachythecium rutabulum (L) B. and S.
Hypnum rutabulum L.
Lake: Lake Bluff (Hill)
Fulton: Liverpool
Capsules: November
Brachythecium salebrosum (Hoffm.) B. and S.
Hypnum salebrosum Hoffm.
Cook: Evanston; S. Chicago (Hill)
Lake: Lake Bluff (U of I)
Will: Joliet (U of I)
Capsules: September, November, June
Bryhnia gramicolor (Brid.) Grout
Eurhynchium sullivantii J. and S., *Hypnum sullivantii* Spruce
Fulton, Menard: (Wolf, Hall)
Bryhnia novae-angliae (S. and Lesq.) Grout
Brachythecium novae-angliae J. and S., *Hypnum novae-angliae* S. and Lesq.
Locality not mentioned: (Wolf, Hall)
Cirriphyllum boscii (Schwaegr.) Grout
Hypnum boscii Schwaegr.
Cook: Glencoe (Calkins)
Peoria: (U of I)
Union: (U of I)
Menard: (Wolf, Hall)
Eurhynchium hias (Hedw.) J. and S.
Hypnum hias Hedw.
Cook: Glencoe; N. Chicago (Hill)
Lake: Lake Forest; Lake Bluff (Hill)
Will: Mokena (Hill)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)

Eurhynchium serrulatum Hedw.
Rhynchostegium serrulatum (Hedw.), *Hypnum serrulatum* (Hedw.)
Cook: S. Chicago; Wildwood; Beverley Hills; Thatcher's Park (U of I)
Champaign: Urbana (U of I)
Kankakee: Kankakee (U of I)
Ogle: Oregon (U of I)
Marion: (Bebb)
Rock Island: Port Byron (Harper)
Peoria: (Brendel)
Eurhynchium strigosum (Hoffm.) Br. and Sch.
Hypnum strigosum Hoffm.
Menard: Marion (Wolf, Hall) (Bebb)

ENTODONTACEAE

Entodon brevisetus (Hook and Wils.) J. and S.
Cylindrothecium brevisetum B. and S.
Champaign: Urbana (U of I)
Will: Crete (Umbach)
Henry: Geneseo (Harper)
Marion: (Bebb)
Menard: (Wolf, Hall)
Entodon cladorrhizans (Hedw.) C. M.
Cylindrothecium cladorrhizans Sch.
Cook: Barrington (Hill)
Lake: Lake Forest; Lake Bluff (Hill)
Will: Crete (Hill)
Champaign: Urbana, Mahomet (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Capsules: June, July
Entodon compressus C. Mueller
Cylindrothecium compressus B. and S.
Champaign: Urbana; Mahomet (U of I)
Kankakee: Kankakee (Hill)
Lake: Lake Bluff (Hill)
Fulton, Menard: (Wolf, Hall)
Entodon seductrix (Hedw.) C. M.
Cylindrothecium seductrix Sull.
Cook: Barrington; River Forest; Riverside (Hill)
Lake: Lake Forest (Hill)
Will: Homer (Hill)
Stark (U of I)
Champaign: Urbana; Mahomet (U of I)
Rock Island: Port Byron (Harper)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Capsules: August, September, October, November, December

Entodon sullivatii Sull.
Peoria: (U of I)

PLAGIOTHECIACEAE

Plagiothecium denticulatum (L.) B. and S.
Hypnum denticulatum L.
Cook: Wildwood; Palos; Glencoe (U of I) (Hill)
Plagiothecium denticulatum var. laetum (B. and S.) Lindb.
Cook: (Taylor)
Ogle: Oregon (Hill)
Capsules: July
Plagiothecium deplanatum Sch.
Hypnum deplanatum Sull.
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Plagiothecium elegans (Hook) Sull.
Hypnum elegans Hook
Will: Joliet (U of I)
Plagiothecium micans (Swartz) Paris
Cook: Wildwood (Hill)
Capsules: May
Plagiothecium micans var. albulum (C. M.) Aust.
Fulton, Menard (Wolf, Hall)
Plagiothecium silesiacum (H. and W.) Hedw.
Menard: Athens (Hall)
Plagiothecium sylvaticum var. sullivantii Sch.
LaSalle: Starved Rock (U of I)

SEMATOPHYLLACEAE

Raphidostegium adnatum (Mx) B. and S.
Hypnum microcarpon Lesq. and J.
Cook: Evanston (Hill)
Will: Joliet (Hill)
Kankakee: Kankakee (Hill)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)

HYPNACEAE

Platygyrium repens (Brid.) B. and S.
Cook: Barrington; Evanston; Niles; LaGrange (Hill)
Will: Lockport; Homer (Hill)
Lake: Lake Bluff (Hill)
LaSalle: Utica (Hill)
Pylaisia intricata (Hedw.) R. and C.
Pylaisia velutina B. and S.
Henderson: Oquawka (U of I)

Pylaisia polyantha (Schreb.) B. and S.
Leskea polyantha Hedw.
Fulton: (Wolf, Hall)
Pylaisia schimperi Cardot
Pylaisia intricata B. and S.
Cook: Evanston; Riverside; Calumet; Sag Bridge (Hill)
Will: Crete (U of I)
Champaign: Urbana (U of I)
Pylaisia subdenticulata B. and S.
Pylaisia denticulata Sull.
Fulton, Menard: (Wolf, Hall)
Hypnum crista-castrensis L.
Ptilium crista-castrensis (L) DeNot.
Fulton, Menard: (Wolf, Hall)
Hypnum curvifolium Hedw.
Cook: Highland Park (Hill)
Lake: Lake Forest; Wauconda (Hill)
Champaign: Urbana (U of I)
Union: (U of I)
Marion: (Bebb)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Hypnum dimorphum Brid.
Heterocladium dimorphum B. and S.
Fulton: (Wolf, Hall)
Hypnum diversifolium Sch.
Menard: (Wolf, Hall)
Hypnum haldanianum Grev.
Lake: Lake Forest (Hill)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Hypnum imponens Hedw.
Champaign: Urbana (U of I)
Marion: (Bebb)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Hypnum micans Schwartz var. albulum (C. M.) Aust.
Isopterygium micans Schwartz.
Fulton, Menard: (Wolf, Hall)
Hypnum pallescens (Hedw.) B. and S.
Ogle: Liberty Hill; Oregon (U of I)
Hypnum patientiae Lind.
Lake: Wauconda (Hill)
Hypnum subimponens Lesq.
Ogle: Oregon (U of I)
Peoria: (Brendel)
Hypnum tenuirostris B. and S.
Hypnum cylindrocarpum C. Muel.
Menard: (Wolf, Hall)

HYLOCOMIACEAE

Hylocomium triqetrum (L. and S.)
Cook: Highland Park; Glencoe (Hill)
Lake: Lake Forest (Harper)
Menard: Athens (Hall)

POLYTRICACEAE

Catharinea angustatum Brid.
Atrichum angustatum B. and S.
Cook: Thornton; Beverley Hills; Berwyn; W. Pullman; Glencoe (Hill)
Lake: Lake Forest (Hill)
Kankakee: Kankakee (U of I)
Champaign: Urbana; Mahomet (U of I)
LaSalle: (U of I)
Rock Island: Moline; Port Byron (U of I) (Harper)
Marion: (Bebb) (U of I)
Hancock: Augusta (Meade)
Peoria: (Brendel) (U of I)
Fulton, Menard, Johnston: (Wolf, Hall)
Capsules: July, August, September, November
Catharinea undulata (L.) W. and M.
Atrichum undulatum Beau.
Cook: Glencoe; Winnetka; Highland Park; Glenwood (Hill) (U of I)
Lake: Lake Forest (Hill)
Kankakee: Rock Creek, Kankakee (Hill)
Champaign: Urbana (U of I)
Henderson: Oquawka (U of I)
Peoria: Princeville (Brendel) (U of I)
Fulton, Menard: (Wolf, Hall)
Capsules: March, February, August, October, November
Catharinea undulata var. attenuata
Cook: Orland (Hill)
Capsules: December
Pogonatum brevicaule (Brid.) Beau.
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Polytrichum commune L.
Cook: Glenwood (Taylor) (U of I)
Lake: Grant Twp. (U of I)
Menard: Athens (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Polytrichum formosum Hedw.
Menard, Union: (Wolf, Hall)

Polytrichum juniperinum Wild.
Cook: Glenwood (U of I)
Will: Crete (U of I)
LaSalle: Starved Rock (U of I)
Ogle: Oregon (U of I)
Henderson: Oquawka (U of I)
Peoria: (Brendel)
Fulton, Menard: (Wolf, Hall)
Capsules: June, July
Polytrichum ohioense R. and C.
Cook: Glenwood (Hill)
LaSalle: (U of I)
Capsules: June
Polytrichum piliferum Schieb.
Ogle: Rock River; Oregon (Hill)
Polytrichum stricta Banks
Lake: Long Lake (Hill)

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THE TERRESTRIAL MOLLUSKS OF TURKEY RUN STATE PARK, INDIANA*

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Turkey Run State Park, lying in Parke County, Indiana, is one of the beauty spots of that state. Covering some 460 acres, it affords a most unusual variety of topographic features for so restricted an area. The park is bisected by Sugar Creek, a stream normally mild and docile but given to periodic floods, at which times it becomes a driving river. Tributary to the creek are a number of smaller streams which have cut their way through sandstone formations of varying hardness, to form ravines replete with waterfalls and other features of scenic beauty. These ravines transect an area of steep hills, all heavily wooded, and give the last touch of beauty to the park. It is, then, an area of streams, abrupt vertical sandstone bluffs, hills, valleys and woods. The ravines are bordered with hemlock (*Tsuga canadensis*), as are in places the river bluffs. The "bottoms" support gigantic sycamores (*Platanus occidentalis*), black walnut (*Juglans nigra*), and elms (*Ulmus americana*). A rich humus covers the ground and acts as an excellent retainer of water, and moss and ferns are abundant throughout the area. The fact that the water is well conserved is indicated by the abundance of terrestrial mollusks found within the park, 46 species having thus far been collected. Classes in geology, entomology, botany, and zoology from a number of mid-western universities visit the park annually to study the biological aspects of the region.

The molluscan fauna is so rich and so much in evidence that it has been thought advisable to offer a list of the terrestrial species found within the park, with some brief notes on the ecology of the species concerned, and it is hoped that further papers dealing with the life of this interesting region may be forthcoming. The present paper, dealing with the terrestrial mollusks, is offered as the first of such a series. Collections have been made during the past three years throughout the park, and hundreds of shells have been collected and identified. In the spring the ground is

* Contribution from the Zoological Laboratory of the University of Illinois, No. 356.

fairly strewn with "dead shells," the remains of animals that died during the winter, washed out by the spring freshets. The high water has washed together great masses of drift and fine debris in the form of windrows. Innumerable specimens of the smaller species may be found by picking over these masses. Indeed, such windrows offer the most profitable collecting if only a variety of species is desired. Many live snails were brought into the laboratory and their rate of progression tested and timed. All the

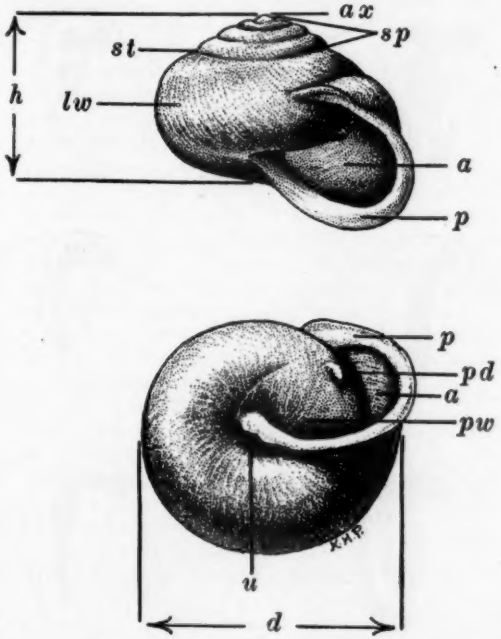
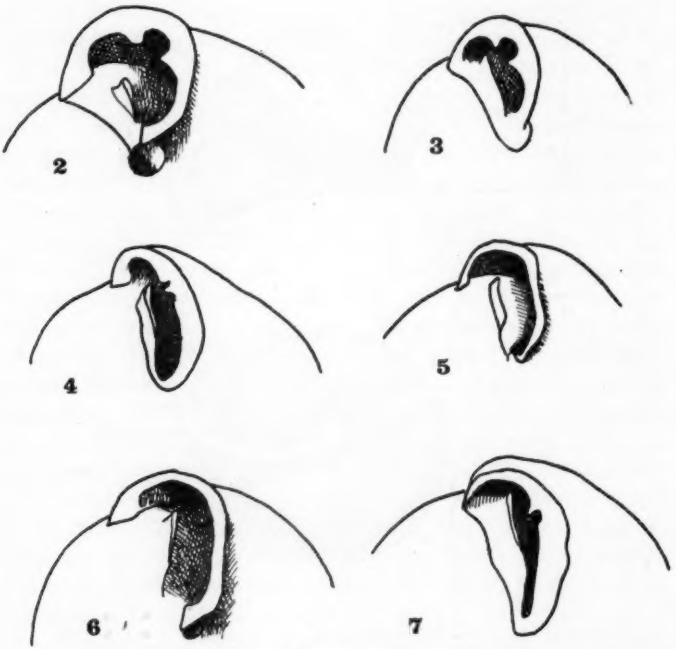


FIG. 1. *Polygyra thyroides*, a typical globulose land shell: *a*, aperture; *ax*, apex; *d*, diameter; *h*, height; *lw*, last whorl; *p*, peristome; *pd*, parietal denticle; *pw*, parietal wall; *sp*, spire; *st*, suture; *u*, umbilicus.

species herein enumerated have been checked and identified by Professor Frank C. Baker of the Natural History Museum of the University of Illinois, and the collections upon which this paper is based have been deposited with this museum for future reference. To Prof. Baker the writers offer their sincerest thanks and appreciation for his always cheerful cooperation, aid, and encouragement.

In the following key, no attempt has been made to include young or immature specimens, if for no other reason than the fact that it is often quite difficult to distinguish young animals by shell characters alone. And this key deals only with external characters; it is intended as an aid to the amature student who would know what mollusks are present without having to delve into the difficult routine of radula extraction and anatomical dissection.



FIGS. 2-7. Six species of Polygyra: (2) *P. tridentata*, (3) *P. inflecta*, (4) *P. hirsuta*, (5) *P. fraterna*, (6) *P. monodon*, (7) *P. stenotrema*.

KEY TO THE ADULT LAND MOLLUSKS OF TURKEY RUN PARK

In using the following key the first figure represents the character under discussion. This is followed by a figure in parentheses which is the alternative character. If the character referred to by the first figure is the one desired, the figure at the end of the line, also in parentheses, tells you where next to go.

1. (86) External shell present. (2)
2. (39) Shell large, over 12.5 mm in diameter; spire globulose, not turreted. (3)
3. (10) Peristome dentate. (4)
4. (7) Umbilicus open. (5)
5. (6) Denticle curved. *Polygyra tridentata.*
6. (5) Denticle almost straight. *Polygyra fraudulenta.*
7. (4) Umbilicus closed. (8)
8. (9) Size large; denticle large, but not obstructing the aperture. *Polygyra palliata.*
9. (8) Size smaller; aperture somewhat closed by denticle. *Polygyra inflecta.*
10. (3) Peristome non-dentate. (11)
11. (26) Umbilicus open. (12)
12. (21) Umbilicus not partially covered by peristome. (13)
13. (14) Aperture with flaring peristome. *Polygyra profunda.*
14. (13) Peristome without flare. (15)
15. (20) Spire flattened. (16)
16. (19) Shell without color bands. (17)
17. (18) Umbilicus narrow, deep. *Omphalina fuliginosa.*
18. (17) Umbilicus wide, showing whorls. *Circinaria concava.*
19. (16) Shell with many color bands. *Anguispira alternata.*
20. (15) Spire not flattened; last whorl with two parallel brown bands. *Anguispira solitaria.*
21. (12) Umbilicus partially overhung by peristome. (22)
22. (23) Size large, over 20 mm; shell coarsely striated; occasionally a trace of rudimentary parietal denticle. *Polygyra thyroides.*
23. (22) Size under 15 mm; striae fine; no trace of parietal denticle. (24)
24. (25) Peristome with wide flare. *Polygyra clausa.*
25. (24) Peristome without flare. *Gastrodonta ligera.*
26. (11) Umbilicus closed. (27)
27. (32) Parietal denticle present. (28)
28. (29) Spire flattened. *Polygyra appressa.*
29. (28) Spire high. (30)
30. (31) Denticle large, conspicuous. *Polygyra elevata.*
31. (30) Denticle small, rudimentary. *Polygyra zaleta.*
32. (27) Parietal denticle absent. (33)
33. (36) Shell large, approximately 25 mm or more in diameter; peristome widely reflected, flattened. (34)
34. (35) Shell with many reddish brown bands. *Polygyra multilineata.*
35. (34) Shell without color bands. *Polygyra albolabris.*
36. (33) Shell smaller, approximately 15 mm or less; peristome without widely reflected flare. (37)
37. (38) Whorls 6; diameter approximately 12.5 mm. *Polygyra mitchelliana.*

38. (37) Whorls 7; diameter approximately 15 mm. *Polygyra pennsylvanica.*
39. (2) Shell small, 10 mm or less in diameter. (40)
40. (51) Parietal denticle present. (41)
41. (50) Shell not turreted: globulose. (42)
42. (49) Denticle nearly closing aperture. (43)
43. (44) Umbilicus open; shell not sculptured. *Polygyra monodon.*
44. (43) Umbilicus closed. (45)
45. (48) Denticle large, making aperture slit-like; peristome notched. (46)
46. (47) Diameter 9 mm. *Polygyra stenotrema.*
47. (46) Diameter 8 mm; rare. *Polygyra hirsuta.*
48. (45) Denticle large, but aperture not slit-like; peristome not notched. *Polygyra fraterna.*
49. (42) Parietal denticle not nearly closing aperture; size less than 3 mm; shell highly sculptured. *Strobilops affinis.*
50. (41) Shell highly turreted. *Gastrocopta armifera.*
51. (40) Parietal denticle absent. (52)
52. (65) Spire elongated, turreted. (53)
53. (58) Shell 3 mm high or over. (54)
54. (55) Aperture equal to more than half of the height of spire. *Succinea avara.*
55. (54) Aperture much less than half the height of spire. (56)
56. (57) Diameter of first whorl equal approximately to ½ the height of spire, which is acutely graduated. *Pomatiopsis cincinnatiensis.*
57. (56) Diameter of first whorl equal approximately to ⅓ the height of spire which is slender and not acutely graduated. *Pupoides marginatus.*
58. (53) Shell 2 mm high or less. (59)
59. (62) Shell approximately 2 mm high. (60)
60. (61) Whorls 4; last whorl with lateral notch. *Vertigo ovata.*
61. (60) Whorls 5; notch absent. *Gastrocopta contracta.*
62. (59) Shell a scant 2 mm high, or less. (63)
63. (64) Apex obtuse; whorls 5. *Carychium exiguum.*
64. (63) Apex acute. *Gastrocopta pentadon.*
65. (52) Spire depressed, not highly turreted. (66)
66. (75) Umbilicus large. (67)
67. (72) Shell over 4 mm in diameter. (68)
68. (71) Surface heavily sculptured or ribbed. (69)
69. (70) Umbilicus shallow, flaring, showing clearly all volutions to the apex; whorls 6. *Goniodiscus perspectiva.*
70. (69) Umbilicus deep, narrow, more precipitate; whorls 5. *Goniodiscus anthyoni.*
71. (68) Surface finely sculptured. *Zonitoides limatula.*
72. (67) Shell 3 mm or less in diameter. (73)
73. (74) Umbilicus flaring and very shallow, showing whorls to apex; dorsal surface flat, disc-like. *Helicodiscus parallellus.*

74. (73) Umbilicus narrow, precipitate. *Vallonia pulchella.*
75. (66) Umbilicus relatively small, dot-like. (76)
76. (79) Shell diameter under 3 mm. (77)
77. (78) Shell heavily sculptured; globulose. *Strobilops labyrinthica.*
78. (77) Shell finely sculptured; flattened. *Pseudohyalina minuscula.*
79. (76) Shell diameter over 3mm. (80)
80. (81) Umbilicus so small as to be almost obliterated. *Glyphyalina indentata.*
81. (80) Umbilicus small, but distinctly open. (82)
82. (85) Aperture widely expanding, ovate. (83)
83. (84) Whorls tightly coiled, regular. *Zonitoides arborea.*
84. (83) Whorls loose, irregular; last whorl dilate. *Retinella hammonis.*
85. (83) Aperture lunate. *Paravitrea multidentata.*
86. (2) External shell absent. (87)
87. (90) Size large; body mottled. (88)
88. (89) Mantle covering entire body. *Philomycus carolinensis.*
89. (88) Mantle small, anterior. *Limax maximus.*
90. (87) Size small; color blackish, unspotted. *Agriolimax campestris.*

Polygyra tridentata (Say).

This is a very abundant species on the hillsides and on the slopes of the tributary ravines. It is most often found under logs in moist situations, or under the loose bark of decomposing logs. Dead shells are conspicuous in the spring, showing that many individuals are winter killed. The species is slow in its movements, progression being at the rate of 2 inches in 130 seconds. A number of shells found under logs in the early spring show that the animal is used as food by some species of mouse. (Fig. 2)

Polygyra inflecta (Say).

Abundant on exposed slopes and often associated ecologically with *P. tridentata* under logs in moist situations. Its rate of progression is a trifle faster than that of the preceding species, as it covers 2 inches in 120 seconds. During progression the shell is tilted at a slight angle to the right. It, too, is used for food by mice, and many individuals are winter killed. (Fig. 3)

Polygyra profunda (Say).

This is strictly a woodland species, and an inhabitant of the moist situations under dead and decaying logs. It is not common within the park, and is found more often on the high ground than on the slopes. It is a more rapid moving species than either of the preceeding, covering 2 inches in approximately 60 seconds.

Polygyra albolabris (Say).

This is the largest representative of the genus within the area, and shells measuring 30 mm in diameter are not unusual, though the species is not very common. It frequents hill slopes and is sometimes found crawling about the base of trees. The species hibernates under logs or behind loose bark. The shell is so large and heavy that the animal does not progress upward with any great rapidity, and even on a horizontal plane it covers 2 inches in 70 seconds. Shells have been found bearing the tooth marks of mice, but few have been found in which the mice have succeeded in penetrating the hard covering.

Polygyra zaleta (Binney).

This is one of the most abundant Polygyrinae within the area, and is found throughout the region. The great numbers of dead shells washed out by the spring freshets indicate a high mortality during the winter. The animal inhabits moist situations under leaves, stones or wood, and feeds almost exclusively on the ground stratum of vegetation.

Polygyra multilineata (Say).

This beautifully shelled species is distinctly uncommon within the park, and there are but four specimens in the writers' collection. All four were found living under the loose bark of a highly rotten elm trunk, being nearly buried in the loose, moist but powdery debris. The trunk was lying in a very moist, swampy spot at the edge of Sugar Creek, showing the species' preference for moisture. Its rate of speed is 2 inches in 55 seconds.

Polygyra palliata (Say).

Not uncommon under logs and debris in moist situations, and quite frequently associated with *P. tridentata* and *inflecta*. More common on exposed hillsides than in the highland woods, and the number of dead shells indicates again a high winter mortality. The young *palliata* often ascend vegetation to a height of a foot or more above the ground, but the adults frequent the ground stratum. In fully mature specimens the umbilicus is closed, but in the young it is widely open, and all stages may be found between the two extremes, depending on the age of the individual. Specimens on hand seem to indicate that it requires three years before the animal is mature and the umbilicus closed.

Polygyra elevata (Say).

Another of the extremely abundant species, found throughout the area, but more frequently on exposed slopes than among living timber. Again, dead shells are strikingly abundant in the spring, perhaps more of this species being found than of any other member of the genus. The adults live under logs and feed on the ground stratum. The rate of progression is 2 inches in 70 seconds.

Polygyra pennslyvanica (Green).

A very rare species within the park, but three specimens having been collected in three years. All came from under moist logs on ravine slopes, and all were living specimens. The progression is 2 inches in 45 seconds.

Polygyra thyroides (Say).

A very abundant species. These animals show a preference for woods rather than for open spaces and may be found under logs and debris in the woods, quite away from water, but only if moisture is held by the protecting shelter. On May 11, 1927, a female was found under the bark of a huge rotting elm tree in the act of laying her eggs in what apparently was the excavation of the Betsy beetle (*Passalus cornutus*). Thirty seven eggs had already been deposited when discovered, and twenty-six more were promptly laid in the vial to which she was transferred, the handling not seeming to affect ovulation in the least. The eggs varied from 3.0 to 3.2 mm in diameter, and hatched in 24 days at room temperature. The rate of progression is 2 inches in 55 seconds.

Polygyra clausa (Say).

Very rare within the park. Two living specimens have been found, and one dead shell. The living specimens were under rotten wood in association with *P. thyroides* and *tridentata*, and were completely buried in the loose debris of a rotten oak stump.

Polygyra mitchelliana (Lea).

Two living specimens and two dead shells are the only representatives of this species so far found. The living animals were crawling on the under surface of a sloping rock in a sheltered ravine. One of the dead shells contained the remains of the animal which had but recently died; the other had been opened by mice. The rate of progression is 2 inches in 70 seconds.

Polygyra hirsuta (Say).

The typical *hirsuta* is very rare here, and is easily confused with the similar *monodon*, *stenotrema* and *fraterna*, which are common. It is found under moist wood and leaves. It differs from *monodon* in having a closed umbilicus; from *fraterna* in that the parietal denticle nearly closes the aperture; and from *stenotrema* in being smaller and less globulose. Progresses at the rate of 2 inches in 135 seconds. (Fig. 4)

Polygyra fraterna (Say).

Common under moist logs, pieces of bark, leaves and sometimes under stones. It is fairly uniformly distributed, but is less common

in the highland woods than on the slopes. Some dead shells are found, but far less frequently than in the case of *stenotrema;* the number of dead shells is entirely out of proportion to the relative abundance of the two species. The rate of progression is 2 inches in 120 seconds. (Fig. 5) In old dead shells the denticle sometimes drops off without leaving a scar, and may cause some confusion in identifying the shell.

Polygyra mondon (Rackett).

Very common on exposed slopes where it lives under moist wood and in decaying logs. Occasionally met with among the lower vegetation two feet above the ground, especially after rain. Its rate of progression is about 2 inches in 120 seconds, though in the laboratory the animals exhibited a strong dislike toward covering the arbitrarily standard 2 inches without pause. (Fig. 6)

Polygyra stenotrema (Ferussac).

The most abaundant of the four rather similar Polygyrinae. They inhabit moist situations under logs and piles of leaves, and are frequently discovered under loose bark. The number of dead shells brought out by the spring freshets is little short of astonishing, and leads one to speculate as to whether the species may not be normally short lived. Frequently shells are found that have been opened by mice, and nine shells of this species were found in the nest of the house *Peromyscus leucopus noveboracensis.* The rate of progression is 2 inches in 100 seconds. (Fig. 7)

Polygyra fraudulenta (Pilsbry).

A common species, often associated with *P. tridentata* under moist logs. It is more common on hill sides and along the ravines than in the highland woods. It is frequently fed upon by mice and dead shells are numerous in the spring. The animal is very slow in its movements and timid in its actions, and in the laboratory required 175 seconds to traverse 2 inches, even after it got under way, which was in itself a painfully slow performance.

Polygyra appressa (Say).

Not a common species, and decidedly uncommon in the adult condition. Young, open umblicated specimens are more common than the closed umbilicated adults, and are found under moist bark and under leaves more frequently than under logs. The adult can traverse 2 inches in 65 seconds, while the young do the same distance in 50.

Circinaria concava (Say).

Very abundant throughout the region, though more often dead shells are found than living specimens. Our collections show nineteen dead shells to one living animal, and the numbers of dead shells washed out in the spring again leads one to speculate on the length of life of the species. The shell is rather thin, and the species is

often eaten by mice. The living animals are often found buried in the moist soil under stumps and leaves which hold the desired moisture. They are more common in shaded ravines than on the open hillsides. That they are carnivorous is well known, and the writers have found the animals extended within the shell of *Omphalina fuliginosa* and *Anguispira alternata*, feeding upon its victims. The progression is erratic and the rate is approximately 2 inches in 80 seconds.

Omphalina fuliginosa (Griffith).

Extremely abundant, especially on the hillsides. Apparently the species likes sunshine, for they are seldom found in the highland woods. As in the preceeding species, the shell is relatively thin and affords easy picking for mice which destroy numbers of the forms. Dead shells are common, the pigmented outer layer chipping off within a month or so after the animal dies, leaving the shell white. The rate of progression is 2 inches in 70 seconds.

Retinella hammonis (Ström).

Quite common under bark and in rotten logs; also found under leaves and among debris. The species apparently is gregarious, as it is frequently found in considerable numbers in one location. It is often associated with *Zonitoides arboreus* from which it can readily be distinguished by the rapid enlargement of the last whorl which, in *Z. arboreus* does not enlarge. Progression: 1 inch in 100 seconds.

Glyphyalina indentata (Say).

Five specimens, all dead shells, were collected from a mass of debris washed into a windrow along the bank of Sugar Creek. Two living animals were found under a fallen hickory. The rate of progression is 1 inch in 55 seconds.

Paravitrea multidentata (Binney).

A single dead shell picked out of the debris of a windrow is the only record on hand for the species within the limits of the park.

Zonitoides arboreus (Say).

Very abundant locally under dead logs and bark, and under masses of leaves which hold moisture. The animal is gregarious, and thirty or more are often found in an area six inches square. After heavy rains they ascend the lower shrubs, but do not remain up after the vegetation has once dried off. They can traverse 1 inch in 70 seconds.

Zonitoides limatulus Ward.

One specimen taken from rotten wood is the only record at hand. This was the shell of an animal but recently dead, and was associated with numerous *Z. arboreus*.

Pseudovitrea minuscula (Binney).

This tiny species is not uncommon, but it is so small that it is easily overlooked, as it inhabits the damp interior of rotten wood. It is more often found in highland woods than in lowlands. It is so small and so slow in its movements that it requires more than 200 seconds to traverse an inch.

Gastrodonta ligera (Say).

This prettily sculptured shell is not uncommon under logs, especially those in the wetter lowland localities. The shell is so thin and fragile that it is apparently much prized by mice as an item of food. In the adult the peristome tends to overhang the umbilicus, but this is not the case among young individuals.

Anguispira alternata (Say).

This strikingly marked shell is very abundant throughout the area, but especially on the southern slopes and in the more moist localities. The animals hibernate in the loose soil under logs and are often completely buried. Many dead shells are found in the spring, and of these many show the activity of mice. The remains of nine of these animals were found in the nest of *Peromyscus leucopus noveboracensis*, and a chipmunk (*Tamias striatus*) was observed in the act of eating one. The rate of progression is 2 inches in 80 seconds.

Anguispira solitaria (Say).

Readily identified by the two parallel brown bands which parallel the whorls, this species is found to be common throughout the region. It shows a preference for low ground, and is found under logs and in brush piles, and occasionally crawling over moss-covered rocks. It attains a large size, and specimens 28 mm in diameter are on hand. It covers 2 inches in 75 seconds. Occasionally used as food by mice, but not as frequently as the preceeding species.

Goniodiscus perspectiva (Say).

Fairly common throughout the region under bark and in rotten logs; sometimes under leaves and rarely under rocks. They insist on a considerable amount of moisture and are less frequent on high ground than on low. Dead shells are often encountered in the spring. It is readily distinguished by its heavy sculpturing and by the very wide umbilicus which makes it possible to see the whorls to the apex.

Goniodiscus anthonyi Pilsbry.

This is a rare species in the park, and but three specimens are on hand. It resembles the preceeding species, but is much smaller. All the specimens found were dead, one being but recently dead. All under the bark of one elm trunk partially decayed.

Helicodiscus parallelus (Say).

Often associated with *Zonitoides arboreus*, this species is rather uncommon, but it is occasionally found under bark and in rotting logs. Confined to the lower regions of the slopes.

Succinea avara Say.

Rare within the park, as there are few areas suitable for the species. It is distinctly a wet, swampy form, often associated with vegetation growing out of water. Beyond the limits of the park, in suitable localities, it is fairly common. This is the only "land" snail in the area that is "physaform." It is rather fast in its progression, covering 2 inches in 40 seconds or less.

Strobilops labyrinthica (Say).

A single shell of this tiny animal is the only record the writers so far have collected. This was a dead shell picked out of the fine debris of a windrow.

Strobilops affinis Pilsbry.

Two specimens found in the same windrow and at the same time as the proceeding species are the only records on hand in the park.

Pupoides marginatus (Say).

This acutely turreted little shell is found commonly, but it is local in its distribution. Common among the roots of grass and on or under fallen leaves. It is gregarious, and fifteen or twenty individuals may frequently be found together if one searches carefully. It ascends grass and low vegetation, rarely going above an elevation of a foot, however. Common in the debris of windrows.

Gastrocopta armifera (Say).

Very abundant locally. Like the preceeding species, it frequents grass areas, and may also be found about the roots of trees. It is highly gregarious, and much more common than a superficial examination of the region would indicate. One of the very characteristic shells found in windrows.

Gastrocopta contracta (Say).

This small edition of *G. armifera* is abundant locally, and in similar habitats. It is gregarious, and associated with the preceeding two species. Abundant in windrows, but requires careful search before it is discovered.

Gastrocopta pentadon (Say).

This tiny species is apparently rare, but it is so small that it may well have been overlooked. The single specimen on hand in 1.6 mm in length and was found in the windrow along with *G. contracta* and *armifera*.

Vertigo ovata Say.

Two dead shells, collected from the same windrow and at the same times as the preceeding species, are the only records we have.

Vallonia pulchella Muller.

This is a gregarious species that is not uncommon under logs and bark of decaying trees. More rarely it is found under stones or in the moss overgrowing rocky areas. It prefers the lowland habitats and requires considerable moisture for its habitat.

Carychium exiguum (Say).

Two specimens from the windrow above mentioned, and one living animal from the wet moss covering an old stump are all the records we have. Another tiny species that is easily overlooked.

Pomatiopsis cincinnatiensis Lea.

Apparently rare, as but two specimens have so far been found. These are both dead shells picked from the debris of a windrow.

Philomycus carolinensis (Bosc.).

This is the common slug of the region. It is crepuscular and nocturnal, and may be found during the hours of darkness crawling over the vertical face of the sandstone cliffs and ravines. During the day they seek the dark, either in crevices in the rocks or they disappear under stones and fallen logs. Their slime trails are clearly visible during the day and show the erratic wanderings of the slugs. While they are solitary in their habits, they are so numerous that they appear to be gregarious. When under way they traverse 2 inches in 40 seconds or less.

Agriolimax agestis (Linn.).

Much less common than the preceeding species, this little dark brown, unmottled slug is found under bark and in decaying wood more often than on the face of cliffs. Being also nocturnal, it is sometime associated with *Philomycus carolinensis*, but it is more likely to be met with about the smaller stones on the ground. They traverse 2 inches in 65 seconds. This is the only native slug.

Limax maximus (Linn.).

A single specimen of this big slug was found crawling about on the damp stones in the basement of the hotel. It is a European species, most often found in greenhouses. It progresses at the rate of 2 inches in 40 seconds, or less.

MORPHOLOGICAL COMPARISONS OF COPRINAE, APHODINAE AND GEOTRUPINAE (COLEOPTERA, SCARABAEIDAE)*

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INTRODUCTION

Adult scarabaeid beetles have been the subject of but three studies concerned with their external morphology. The first of these, by Straus-Dürckheim (1828) treats the common European cockchafer, *Melolontha vulgaris;* the second, by Willcox (1896), treats *Phyllophaga* (*Lachnosterna*) *fusca,* one of the common June beetles; and the third, by Hayes (1922), covers *Phyllophaga crassissima,* another common June beetle. Straus-Dürckheim's study is beautifully illustrated, but largely beyond use because the author worked under the handicaps of a very new and undeveloped science. Willcox's study is sketchy and of a semi-popular nature, leaving the work of Hayes as the only modern and usable account.† These studies concern three genera of phytophagous scarabs; the large and peculiar group of scavengers is untouched. It is hoped that the present study will offer a better understanding of the life and habits of the latter group.

Three large subfamilies of these scavengers or dung-eaters are represented in Illinois: the Coprinae, the Aphodinae, and the Geotrupinae. Our common tumble-bug, *Canthon laevis* (Drury) was collected for study as a representative of the first subfamily; *Aphodius fimetarius* (L.), the copper-winged aphodius, represents the second subfamily; and *Bolbocerosoma bruneri* Dawson and McColloch, represents the last, selections being made to combine simplicity of structure with ease of collection. The tumble-bug and the copper wing were taken in good numbers at St. Joseph and Urbana, Illinois, while *Bolbocerosoma* came from Rapidan, Minnesota, as well as from Urbana.

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† Since this writing Roger B. Friend has published "The Asiatic Beetle in Connecticut," as Bulletin 304 of the Connecticut Agricultural Experiment Station.

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TAXONOMIC RELATIONSHIPS

A short summary, taken in part from Leng (1921), is given below to show the taxonomic position of the beetle selected from each subfamily for study. Only closely related genera are listed, and the particular one studied is in italics.

Family Scarabaeidae
- **Subfamily Coprinae**
  - **Tribe Scarabaeini**
    - **Genera *Canthon***
      - **Deltochilum**
      - **Megathopa**
  - **Tribe Coprini**
- **Subfamily Aegialiinae**
- **Subfamily Aphodiinae**
  - **Tribe Aphodiini**
    - **Genera *Aphodius***
      - **Oxymus**
  - **Tribe Eupariini**
  - **Tribe Psammobiini**
- **Subfamily Ochodaeinae**
- **Subfamily Hybosorinae**
- **Subfamily Geotrupinae**
  - **Tribe Bolbocerini**
    - **Genera Bolboceras**
      - **Odontaeus**
      - ***Bolbocerosoma***
      - **Eucanthus**
  - **Tribe Geotrupini**
- **Subfamily Pleocominae**
- **Subfamily Golaphyrinae**
- **Subfamily Acanthocerinae**

Canthon heads the list as the simplest in structure. *Aphodius* follows, occupying a position between *Canthon* and *Bolbocerosoma*. Scarabs can be recognized by the lamellate antennae (Figs.

35, 36, 37) and the fact that the epimera of the mesothorax extend to the coxae (Figs. 53, 54, 55).

The three subfamilies represented in this study have the following structural modifications in common, according to Dawson (1922): "Abdominal spiracles situated in the membrane connecting the sternites and tergites, the last spiracle covered by the elytra; ligulae always distinct from the mentum; the species all living on decomposing organic matter, many of them in excrement and a few in dung."

The Coprinae are further modified so that they may be known by the short and rounded outline, expanded clypeus which hides the mouthparts from dorsal view; hind tibiae usually with a single spur; last tarsal segment usually without the two erect setae between the claws; elytra truncate; pygidium exposed and abdomen with six firmly united sternites.

Aphodinae are small beetles of cylindrical form bearing two spurs on the posterior tibiae; entire elytra covering the pygidium; free sternites and bearing two erect setae on the fifth tarsal segment, between the claws. Mandibles and labrum are rarely visible from above.

Geotrupinae are rounded and convex, of good size, with prominent mandibles and labrum, 11-segmented antennae, and covered pygidium.

HABITS

Digging is an important bit of work of any scarab and is doubly important to the dung-eaters. All of them have broadened front tibiae with scalloped margins (Figs. 50, 51, 52) and so arranged that they can be swung into use front and side where they are most efficient in scraping away the soil. Dung eating is another common habit but its demands are not answered so uniformily; *Canthon* and *Aphodius* have soft and sensitive labrum, maxillae and mandibles (Figs. 25, 28, 31, 33) easily useful in manipulating the soft food. These parts are hidden from dorsal view by the clypeus which is broad and scoop-like (Figs. 7, 9) so that dung and dirt may be "nosed" aside by upward thrusts of the head. *Bolbocerosoma* departs from this, its mandibles, maxillae, and labrum (Figs 29, 34) being strongly chitinized and exposed by a normal clypeus (Fig. 11).

Canthon spends a large part of its time above ground in the sun, walking, flying, and modelling dung balls. Long and fairly

thin legs give it the freedom that neither *Aphodius* nor *Bolbocerosoma* have or demand in their subterranean life. Its legs are bowed in addition. so that it may grasp its dung ball with pincher-like effect, its hind and middle tarsi being well set with spines to facilitate holding and manipulating it.

Aphodius spends most of its time burrowing in the dung of cows or horses, a soft medium. It uses its sturdy hind and middle legs in horizontal piston-like thrusts to push the body along. These hind and middle legs are made up of a succession of cone-like swellings each crowned with a half-circle of spines that are effective on the backward thrust but slip easily through the dung when pulled forward.

Bolbocerosoma is one of the earth borers, so called because it digs straight and narrow tubes into the earth. Its legs, like those of *Aphodius,* are sturdy, and are also spined, enabling it to clamber up and down in its perpendicular burrow. The body, as nearly a perfect hemisphere as that of any insect, enables the beetle to pivot on its legs anywhere in the burrow and "about face," doing away with the necessity of a chamber in which to turn.

SIZE, SHAPE, AND COLOR

Both the dorsal and ventral surfaces of *Canthon* (Fig. 1) are convex, the ventral structures thereby being thrown into view. Even the propleuron is easily visible. A dorsal outline is broad through the elytra, tapering gently toward either end. *Aphodius* (Fig. 4) is cylindrical in dorsal view, its ends rounding off abruptly. Laterally it shows much less of the ventral structures than *Canthon,* in which the vertical distance from the dorsum to the edge of the elytra does not exceed the vertical distance from the edge of the elytra to the ventral surface. The prothorax is prolonged ventrally so as to cover most of the pleuron from lateral view. In *Bolbocerosoma* (Fig. 5) all of the pleuron is hidden from this view. The abdomen, meso- and metasterna are intermediate in convexity between those of *Canthon* and *Aphodius.*

Genus	Color	Length	Shape
Canton.	Dull black, slightly bronzed.	11-19 mm.	Sub-ellipsoidal.
Aphoduis.	Shining black, and coppery.	6.5-8.5 mm.	Sub-cylindrical.
Bolbocerosoma.	Black and orange.	10-13 mm.	Sub-hemispherical.

EXTERNAL SEXUAL DIFFERENCES

The antennae, which frequently show sexual dimorphism in Sscarabaeidae, show none in these three species. Where cephalic tubercles occur, as in *Aphodius* and *Bolbocerosoma,* they are more prominent in the male than in the female. In *Bolbocerosoma* those which lie on the meson of the female are represented by a horizontal ridge in the male. Males of *Canthon* show a deeper emargination of the ninth sternite than do the females (Fig. 2). *Bolbocerosoma* (Fig. 6) approaches this difference; the ninth sternite of the males is truncate at the tip, while that of the females is not. Males of *Canthon* are peculiar in having the protibial spur broadened at its distal end (Fig. 3).

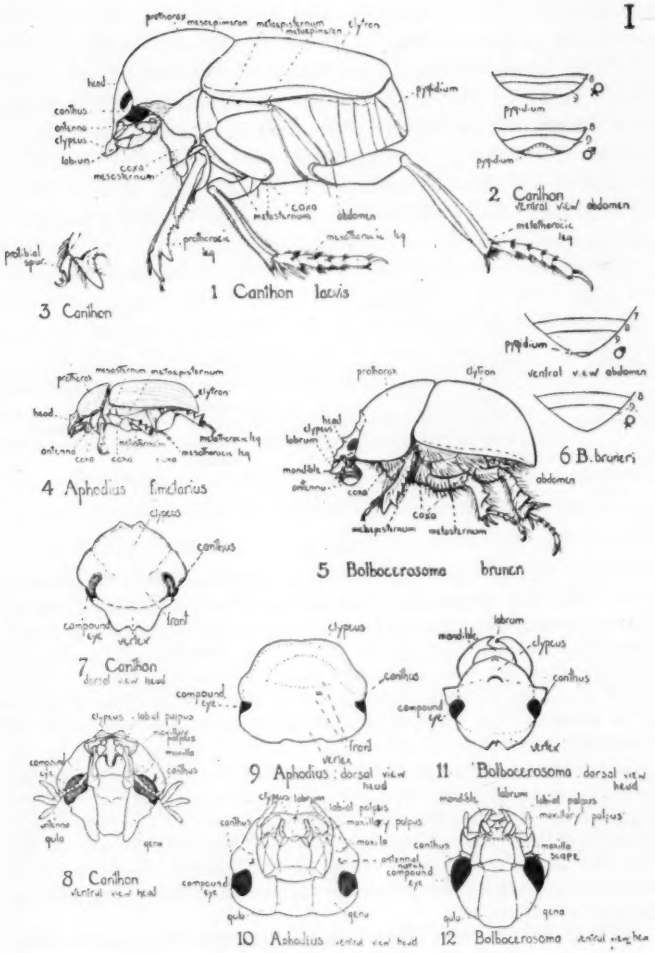
Genus	Female	Male
Canthon.	Protibial spur slender, pointed. Last sternite with shallow notch.	Protibial spur triangular or bifurcate. Last sternite with deeper notch.
Aphodius.	Cephalic tubercles small. Lacks dorsal prothoracic depression.	Cephalic tubercles larger. Dorsal depression on pro throax.
Bolbocerosoma.	Cephalic tubercles small.	Cephalic tubercles larger.

HEAD

Dorsal Aspect: The most striking difference occurs in *Bolbocerosoma* (Fig. 11) which has both its mandibles and labrum plainly visible and chitinous. The clypeus is not expanded, occurring as a subrectangular piece distad of the front. In *Canthon* (Fig. 7) and *Aphodius* (Fig. 9) both mandibles and maxillae are hidden by the greatly expanded clypeus which is fused with the canthus along its lateral margin. The canthus of *Bolbocerosoma* is not fused with the clypeus and is angular.

Both clypeus and front in *Canthon* are without tubercles although two teeth occur, one on each side of the meson along the cephalic margin of the clypeus. The front in *Aphodius* bears three tubercles in a transverse row; that of *Bolbocerosoma* is similarly armed in the male, but bears a transverse ridge in the female. Both sexes of *Bolbcerosoma* bear a tubercle on the clypeus in addition, but those of *Aphodius* are unarmed.

Ventral Aspect: The ventral view of the head of *Aphodius* (Fig. 10) is striking in being dilated laterally to such an extent as to leave the articulations of the maxillae, and the entire inner margin of the eye exposed to view. These parts in *Canthon* and *Bolbocerosoma* are hidden by the base of the maxilla. In both *Canthon* and *Aphodius* the clypeus appears ventrally, but in *Bolbocerosoma* it does not. The latter shows its mandibles in this view.


I
prothorax
mesepimeron
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elytron
metepimeron
head
pygidium
canthus
antenna
clypeus
labium
coxa
mesosternum
coxa
metasternum
abdomen
prothoracic leg
mesothoracic leg
metathoracic leg
tibial spur
1 Canthon laevis
2 Canthon ventral view abdomen
3 Canthon
4 Aphodius fimetarius
5 Bolboceroso brunea
6 B. brunneri
7 Canthon dorsal view head
8 Canthon ventral view head
9 Aphodius dorsal view head
10 Ashodius ventral view head
11 Bolboceroso dorsal view head
12 Bolboceroso ventral view head
clypeus
canthus
front
vertex
compound eye
labrum
mandible
labial palpus
maxillary palpus
maxilla
antennal notch
scape
gula
gena

PLATE I.

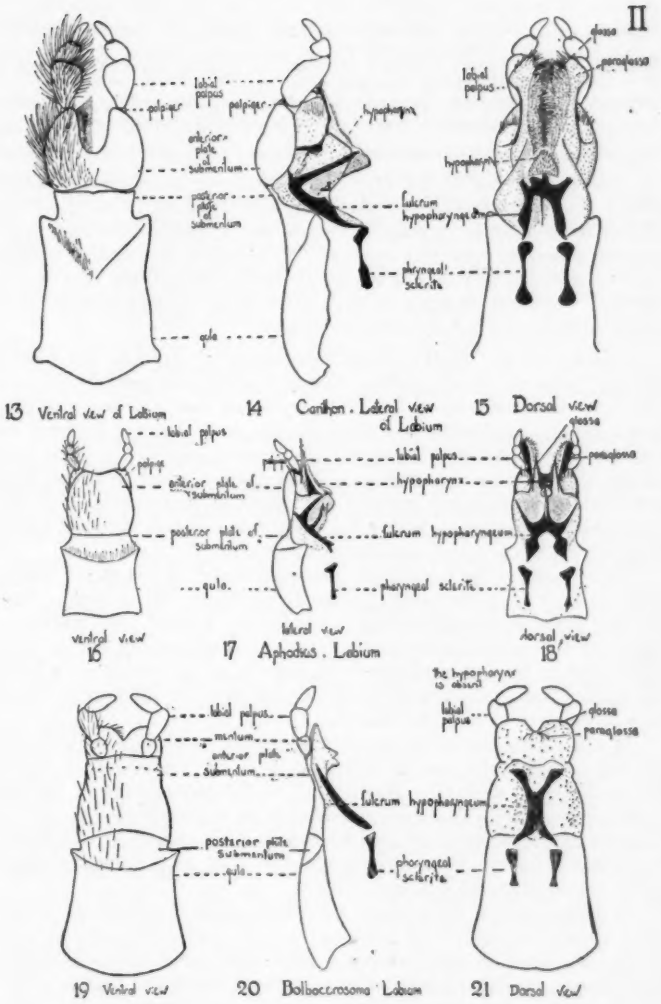

II
glossa
paraglossa
labial palpus
palpiger
anterior plate of submentum
posterior plate of submentum
gula
hypopharynx
fulcrum hypopharyngeum
pharyngeal sclerite
13 Ventral view of Labium
14 Carabus. Lateral view of Labium
15 Dorsal view
palpus
16 ventral view
17 Aphodius. Labium
lateral view
18 dorsal view
mentum
19 Ventral view
20 Bolbocerosoma Labium
21 Dorsal view

PLATE II.

Genus	Head characters
Canthon.	Clypeus expanded, covering mouthparts, base of antennae hidden by maxillae.
Aphodius.	Clypeus expanded covering mouthparts, base of antennae not hidden by maxillae.
Bolbocerosoma.	Clypeus not much expanded, mandibles and labrum visible dorsally. Base of antennae hidden by maxillae.

Antennae (Figs. 35, 36, 37): *Bolbocerosoma* is unique in having eleven antennal setments and almost circular lamellae in its club. Its pedicle is not modified greatly. *Canthon* and *Aphodius* have nine segemented antennae with oval lamellae. The pedicle of *Canthon* is only slightly modified and that of *Aphodius* distinctly modified as a larger segment. *Canthon* is alone in having the distal margin of those segments between the pedicle and club dilated.

Labrum (Figs. 13–21): The labial palpi of *Canthon* are distinguished by being greatly swollen and in having each segment shorter than the one preceding it. In *Bolbocerosoma* and *Aphodius* the segments are not so swollen and their lengths are somewhat different in relation to each other: the palpus of *Aphodius* consists of three segments, of which the proximal and distal one are equal in length and the central one distinctly shorter; the palpus of *Bolbocerosoma* is distinguished in its turn by having the distal two segments of about equal length, with the proximal one distinctly shorter.

Other parts of the labium are quite as different as the palpi: There is no trace of the mentum of *Canthon* (Fig. 13) in ventral aspect. The anterior plate of the submentum is enormously bilobed. In *Aphodius* (Fig. 16) the anterior plate is but slightly emarginate and has on each laterocephalic margin a distinct triangular plate upon which are born the palpi. These triangles are labelled "palpigers" in the figure. They may be portions of a divided mentum.

If this interpretation is correct, the mentum of *Bolbocerosoma* is as distinctly visible in ventral view as that of *Lachnosterna* (now *Phyllophaga*) as figured by Hayes (1922). Hardenberg (1907) figures a similar structure of *Bolboceras farctus* (now *Bolbocerosoma farctum*) as fused galea (paraglossa) and believes the mentum to be a narrow transverse plate which he distinguishes caudad of it. Such a plate seems absent in *Bolbocerosoma bruneri*.

A dorsal view of the labium of *Bolbocerosoma* shows all the structures greatly reduced: the hypopharynx is reduced, the glossae and paraglossae fused mesally to form a three lobed membranous tubercle. The fulcrum hypopharyngeum shows only a straight bar in side view.

In *Canthon* the hypopharnyx is a triangular chitinous plate bearing spines and in *Aphodius* it is less chitinous and bears soft hairs. In *Canthon* the paraglossa of either side is partially fused with the glossa. Both form a long tongue-like lobe, chitinized on its outer margin and bearing an abundance of soft hairs on the inner margin.

Those of *Aphodius* are fused throughout their length, are chitinized on the outer margin, and sparsely setaceous on the inner margin. In side view, the fulcrum hypopharyngeum is v-shaped.

Maxillae (Figs. 22, 23, 24): The chitinous distagalea sets *Bolbocerosoma* in its own class. In the other two species it is a membranous lobe heavily setaceous on its dorsal surface. The lacinia of *Bolbocerosoma* is different, being a slightly curved spur whereas that of *Canthon* and *Aphodius* is membranous and setaceous on the dorsal surface. The lacinia of the latter two differ slightly: that of *Canthon* consists of a single lobe while that of *Aphodius* is bi-lobed. The subgalea of *Bolbocerosoma* is peculiar, having a sharp tooth, if my interpretation is correct. Hardenberg (1907) believes this to be a portion of the lacinia, but I find no suture separating it from the subgalea, hence believe it a prolongation.

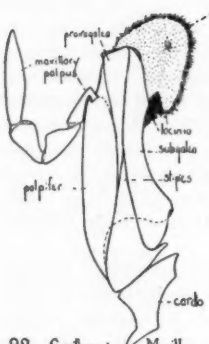
The maxillary palpi are strikingly different: the proximal segment of the palpi of *Canthon* is acutely elbowed; that of *Aphodius* is cylindrical and only very slightly bent; while that of *Bolboceroma* almost escapes observation, being very short and straight. *Canthon* is also peculiar in that the distal segment is longer than the second by one-third while that of the others does not greatly exceed the second in length.

The remaining parts of the maxillae are not greatly differentiated although the proxagalea and stripes of *Canthon* are connected. The general shape of the maxillae of *Bolbocerosoma* is narrow; that of *Aphodius* short and broad; and that of *Canthon* intermediate.

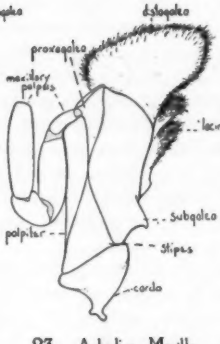
Mandibles (Figs. 25, 28, 29, 30): The mandibles of *Bolbocerosoma* are different in being almost entirely chitinized, the membranous acia being the exception. Each bears a suprabrustia. Dentes are present on the inner apical portions and fit those of the opposing side. In *Canthon* and *Aphodius*, the entire apical half is membranous with its caphalo-mesal portions fitted with soft setae. A prostheca is present on the mandibles of both. Probably the most striking likeness between the three species is the convexity of the right mola and the concavity of the left.

Labrum-epipharynx (Figs. 31, 32, 33, 34): Some interesting differences occur in the development of the labrum-epipharynx. The dorsal view of this structure, or labrum proper will first be treated. It is membranous and bears cephalic setae in *Canthon* (Fig. 31) and Aphodius (Fig. 33). The labrum of *Aphodius* is essentially like it. The clypeus is dilated over it, hiding it from dorsal view. In *Bolbocerosoma* (Fig. 34) the labrum is entirely chitinous and half of its length is exposed cephalad of the clypeus, but it is attached to the clypeus on its ventral surface much as that of the other two and bears cephalic and lateral margins, besides a few others irregularly placed on its flat surface. *Canthon* (Fig. 31) and *Aphodius* are different in having this surface membranous and strengthened by chitinous arches and plates. The setae are more definitely arranged, each epipharynx having a row of measally directed ones near its lateral margin with others scattered laterad and mesad of them. A set of spines on the

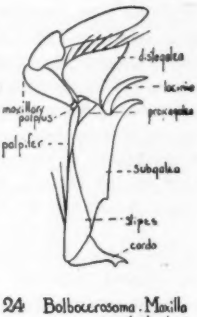
III



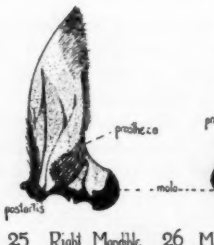
22 Canthon : Maxilla
ventral view



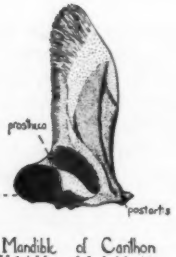
23 Aphodius Maxilla
ventral view



24 Bolboceresoma. Maxilla
ventral view



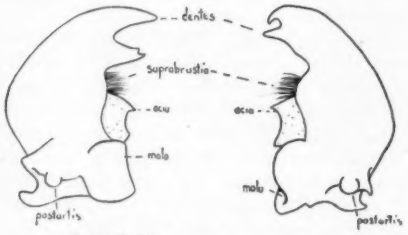
25 Right Mandible
Canthon: Ventral View



26 Mandible of Canthon
Ventral View of Left Mandible

27 Lateral View Canthon.
Right Mandible

28 Right Mandible of
Aphodius
ventral view



29 Mandibles of Bolboceresoma
Right Mandible
ventral view

30 Left Mandible
ventral view

PLATE III.

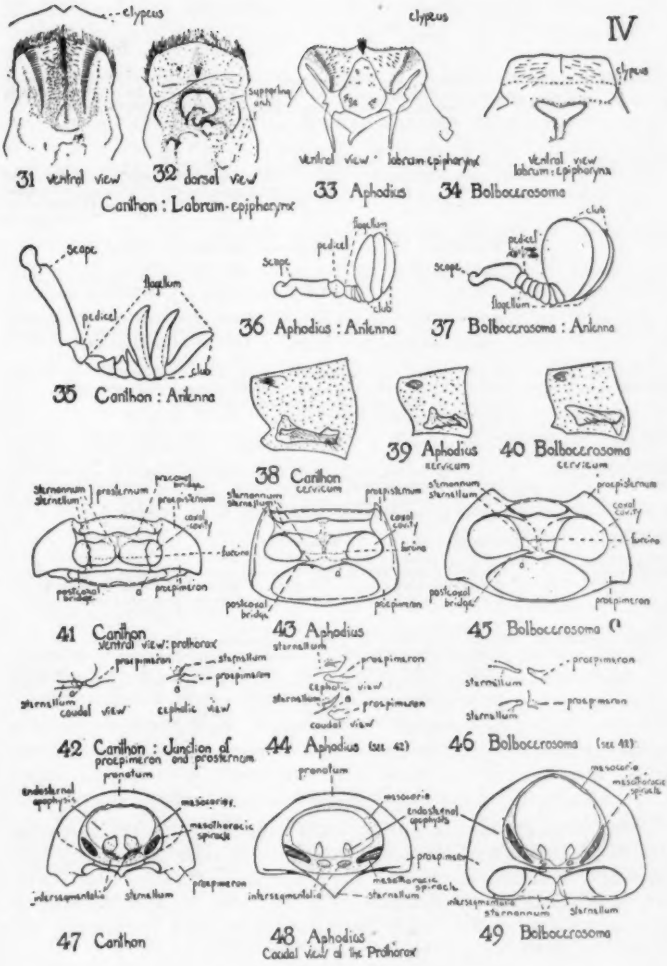

clypeus
supporting arm
31 ventral view
32 dorsal view
Carithon : Labrum-epipharynx
clypeus
ventral view · labrum-epipharynx
33 Aphodius
34 Bolboceratosoma
IV
clypeus
ventral view
labrum-epipharynx
scape
flagellum
pedicel
club
35 Carithon : Antenna
36 Aphodius : Antenna
37 Bolboceratosoma : Antenna
38 Carithon
cervicum
39 Aphodius
cervicum
40 Bolboceratosoma
cervicum
sternum
sternellum
prosternum
procoxal bridge
procoxal cavity
furca
postcoxal bridge
prepimeron
41 Carithon
ventral view: prothorax
43 Aphodius
45 Bolboceratosoma
propimeron
sternellum
caudal view
cephalic view
42 Carithon : Junction of propimeron and prosternum
44 Aphodius (see 42)
46 Bolboceratosoma (see 42)
pronotum
endosternal apophysis
mesocoxa
mesothoracic spiracle
intersegmentalia
47 Carithon
48 Aphodius
Caudal view of the Prothorax
49 Bolboceratosoma

PLATE IV.

meson of the cephalic surface and a mesal, perforated, and triangular plate make the epipharynx of *Aphodius* different from that of *Canthon* which bears a mesal brush-like set of setae.

Parts	Canthon	Aphodius	Bolbocerosoma
Antennae.	9-segmented, lamellae ovoid in outline, pedicle distinctly modified, cephalic portions dialated.	9-segmented, lamellae X ovoid in outline, pedicle distinctly modified.	11-segmented, lamellae subcircular, pedicle unmodified.
Labial palpi.	Greatly swollen, segments successively shorter.	Not swollen, proximal and distal segments equal and longer than middle one.	Not swollen, two distal segments about equal in length, longer than proximal one.
Submentum.	Anterior plate strongly bilobed.	Anterior plate very slightly emarginate.	
Hypopharynx.	Triangular spiny plate	.Triangular setaceous plate.	Reduced, without spines or setae.
Glossae and paraglossae.	Those of either side partially fused to form tongue-like lobes.	Those of either side fused throughout their length.	Fused mesally, forming a 3-lobed membranous tubercle.
Distagalea and lacinia.	Membranous, setaceous. A single membraneous and setaceous lobe.	Membranous, setaceous, bilobed, membranous and setaceous.	Chitinous. A curved chitinous spur.
Subgalea.	Without a spine.	Without a spine.	Bears a spine-like tooth.
Maxillary palpus.	Proximal segment, acutely elbowed, distal segment longer than second by one-third.	Proximal segment only slightly curved, distal and second segments of about equal length.	Prosimal segment very short. Distal and second segments of equal length.
Proxagalea.	Touch each other.	Do not meet.	Do not meet.
Mandibles.	Distal end membranous Prosthecа striated. Covered by cypeus.	Distal end membranous. Prosthecа striated. Covered by clypeus.	Strongly curved, chitinousi Acia alone membranous. Not hidden by clypeus.
Labrum-epipharynx.	Covered dorsally by clypeus, membranous, ventral mesal line bears many setae, triangle absent.	Covered dorsally by clypeus, membranous meso-cephalic border bears set of heavy spines, a chitinous mesal triangle present.	Exposed to view dorsally, Chitinous, a few setae arranged irregularly on each side the mesal line.

CERVICUM

The cervical sclerites do not differ greatly in the three species. The shapes are difficult to describe because of their irregularity, but the small caudo-lateral piece is subtriangular in *Bolbocerosoma* (Fig. 40), sub-rectangular in *Aphodius* (Fig. 39), and possibly sub-oval in *Canthon* (Fig. 38). The larger lateral piece, to which the smaller one is fused in each case, is even more irregular (Figs. 38, 39, 40).

THORAX

Prothorax (ventral aspect) (Figs. 41, 43, 45): The narrow prothoracic and subtriangular pleura of *Canthon* are distinctive. The tip of its post coxal bridge (Figs. 42, 44, 46) is bilobed and articulates in a

double branched socket in the sternellum, while that of *Aphodius* and *Bolbocerosoma* consists of a single lobe fitted into a single socket. In *Aphodius* and *Bolbocersoma*, the pleura are reduced to bands between the ventral edge of the pronotum and the coxal cavities. The outline of the ventral view of the prothorax is subquadrate for *Aphodius* and semicircular in *Bolbocerosoma*.

Prothorax (caudal aspect) (Figs. 47, 48, 49): A caudal view of the prothorax of Aphodius (Fig. 38) shows the sternellum greatly bent donward as compared with the other two species. *Bolbocerosoma* (Fig. 49) is peculiar in showing much of the coxal cavities in this view; in having very elongate mesothoracic spiracles and almost minute intersegmentalia. The intersegmentalia of the other species are much larger.

Prothoracic Legs (Figs. 50, 51, 52): The coxa of each bears a transverse ridge near its distal margin. This is most prominent in *Aphodius*, less so for *Bolbocerosoma* and faint for *Canthon*. The femur of the latter bears on its proximal cephalic surface a slight depression from which grows a great brush of soft setae. This is represented in *Aphodius* by a long brush of similar setae and lost in *Bolbocersoma*. The tibia of each species is characteristic: that of *Canthon* bears three teeth on its lateral margin. Between these, there may or may not be smaller ones, the number varying even on the leg of either side. Between the first prominent tooth and the poximal end of the tibia are about a dozen small ones. The number varies on the leg of either side, and with age or wear. A distal spur, varying in shape with the sex and tarsus of which the first segment is longer than the next three and protected by an expansion of the tibia complete the armature. *Aphodius* also bears three prominent tibial teeth. Smaller ones are present on the proximal portion but none between the larger set. The tarsus is distinct by reason of having its proximal segment shorter than the second and no longer than the third or fourth. The first segment is unprotected. The claws bear two setae between them.

The tibia of *Bolocersoma* is distinguished by its armature of approximately eight teeth which become successively larger from the first to the last. Like the previous two species, it bears a single apical spur. Its tarsus is unprotected and the first four segments are of nearly equal length, distinguishing it from *Canthon* and *Aphodius*.

Meso-and Metasterna (Figs. 53, 54, 55): The metaepimeron of *Aphodius* touches the mesocoxal cavity, distinguishing it from both *Canthon* and *Bolbocersoma*. Both the latter are again distinguished from the first by the fact that the mesoepimeron is prolonged mesally in them so as to reduce the anterior margin of the mesosternum. *Canthon* is in its turn distinguished from *Bolbocerosoma* and from *Aphodius* by having the mesosternum reduced to a narrow band and in having the coxal cavities penetrate deeply into the metasternum.

Mesotergum and Elytra: Canthon stands alone in having more parts than the scutellum easily visible dorsally and in having the mesotergum entirely covered when the elytra are at rest. The tip of

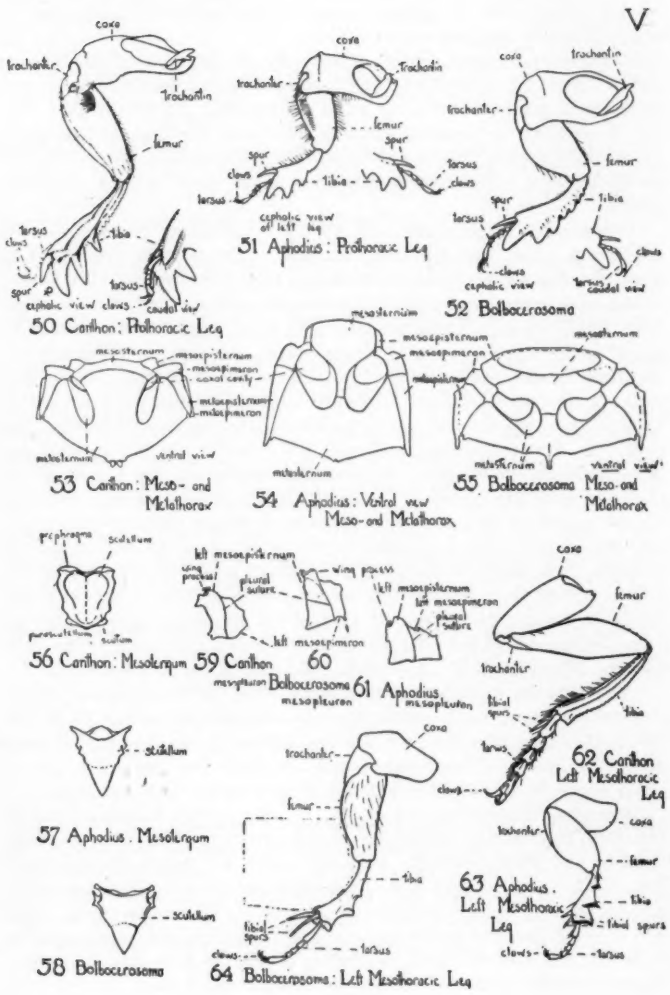

V
coxa
trochanter
Trochantin
femur
tibia
tarsus
spur
clows
cephalic view
caudal view
50 Carithon: Prothoracic Leg
51 Aphodius: Prothorace Leg
52 Bolbocerosoma
mesosternum
mesepisternum
mesepimeron
coxal cavity
metepisternum
metepimeron
metasternum
ventral view
53 Carithon: Meso- and Metathorax
54 Aphodius: Ventral view Meso- and Metathorax
55 Bolbocerosoma Meso- and Midthorax
prepectus
scutellum
parascutellum
scutum
56 Carithon: Mesosternum
left mesepisternum
wing process
pleural suture
left mesepimeron
59 Carithon
60
mesopleuron
Bolbocerosoma
61 Aphodius
mesopleuron
62 Carithon
Left Mesothoracic
Leg
63 Aphodius.
Left Mesothoracic
Leg
57 Aphodius. Mesosternum
58 Bolbocerosoma
64 Bolbocerosoma: Left Mesothoracic Leg

PLATE V.

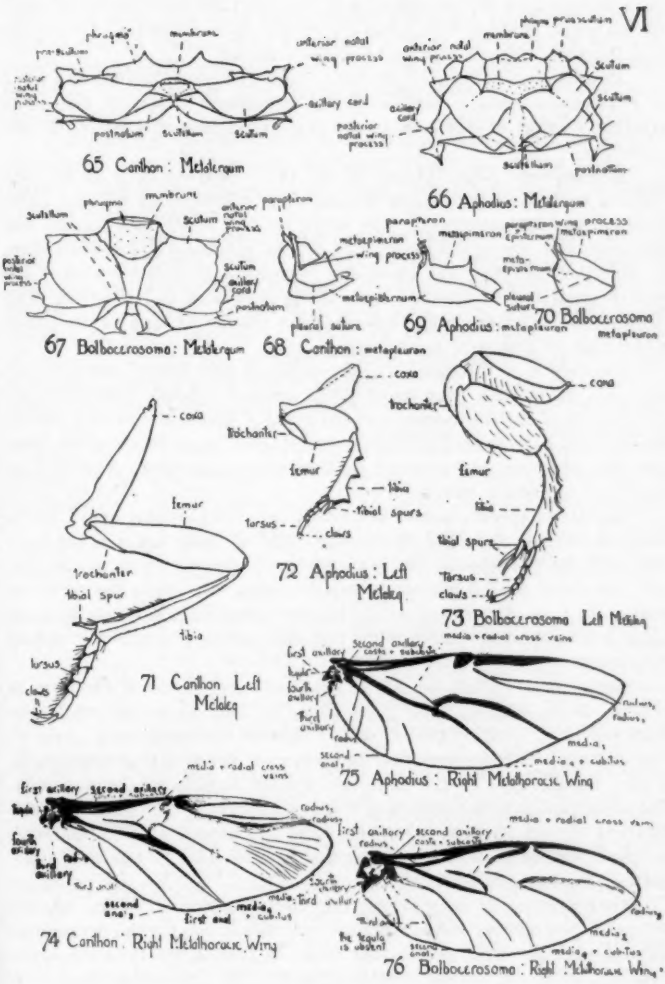

VI
65 Canthon: Metatergum
66 Aphodius: Metatergum
67 Bolboceratoma: Metatergum
68 Canthon: metapleuron
69 Aphodius: metapleuron
70 Bolboceratoma metapleuron
71 Canthon Left Metatarsus
72 Aphodius: Left Metatarsus
73 Bolboceratoma Left Metatarsus
74 Canthon: Right Metathoracic Wing
75 Aphodius: Right Metathoracic Wing
76 Bolboceratoma: Right Metathoracic Wing

PLATE VI.

the scutellum of the remaining species is exposed and assists in locking the elytra in place.

Each elytron of *Canthon* bears eight very faint striae, of which the punctures are visible only on the inner surface; the elytral striae of *Aphodius* and *Bolbocersoma* are stronger and the punctures show on the dorsal surface. Ten striae are visible on each elytron of *Aphodius* and fourteen on each elytron of *Bolbocerosoma.*

Mesopleuron (Figs. 59, 60, 61): *Aphodius* and *Canthon* are alike in having the cephalic portion of the episternum expanded instead of straight as that of *Bolbocerosoma.* The differences are slight in this structure.

Mesothoracic Legs (Figs. 62, 63, 64): *Canthon* falls in its own class in having a somewhat cylindrical coxa embedded by half its thickness in the metasternum. The coxae of the other two species are flattened, also embedded deeply but do not penetrate the metasternum by half their length. The coxae are contiguous in *Bolbocerosoma;* are widely separated in *Canthon,* and barely separated in *Aphodius.* The coxae of both *Canthon* and *Bolbocerosoma* are not as long as the femur while that of *Aphodius* is as long.

The femur of *Canthon* is again flattened and bowed upward, and the tibia fitted with four longitudinal crenate ridges. The femur of *Aphodius* and *Bolbocerosoma* is also greatly flattened but not bowed. The tibia of each bears four transverse ridges; those of *Aphodius* bearing rows of spines and those of *Bolbocerosoma* unarmed. The tibia of the latter is greatly bowed.

The three species agree in having two apical tibial spurs but a slight modification occurs in *Canthons* one of these spurs being very distinctly above the other. It is further separated by its tarsal characters, the claws having two setae between them. Otherwise the tarsus is similar to that of *Bolbocerosoma,* having a proximal segment at least twice longer than the three following, and unlike *Canthon* not having the tarsomeres compressed.

Metatergum (Figs. 65, 66, 67): The metatergum of *Canthon* is narrow, being slightly over three times as long as broad, while the metatergum of each of the other two species not more than twice as long as broad. The long axis of the scutum of *Canthon* is perpendicular to the meson; that of the next two species is directed caudo-mesad. The membranous area common to the metatergum of coleoptera is much different in each of these, it forms a short and narrow area in *Canthon;* is almost square in *Bolbocerosoma,* and intermediate in size and quadrilateral in shape in *Aphodius.*

Metapleurona, Metaepimeron, and Metaepisternum (Figs. 68, 69, 70): *Canthon* and *Aphodius* fall into one class in having the parapteron unfused with the wing process but differ in that in *Canthon* the metaepimeron does not extend caudally beyond the metaepisternum. In *Bolbocerosoma* they end on the same line and the parapteron is closely fused with the cephalic portion of the wing process.

Metathoracic Legs (Figs. 71, 72, 73): Some very distinct variations occur. When in position in the body, the coxa of *Canthon* is

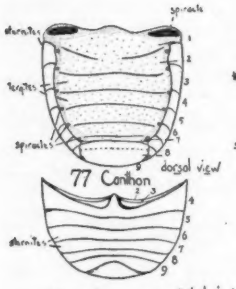
deeply imbedded between the third abdominal segment and the metathorax so that it barely breaks the regular outline. It is not as long as the femur. Two abdominal sternites are entirely concealed from view by it, leaving six exposed. It stands alone in this respect: the coxa of *Aphodius* being longer than the femur; that of *Bolbocerosoma* exactly as long; and both being flattened but not imbedded although they do extend backward so that in *Aphodius* two sternites are concealed and in *Bolbocerosoma* four may not be seen without removing the coxa. The coxae of the three species are alike in being contiguous on the meson.

The femur of *Canthon* is slightly flattened and curved upward being nearly four times as long as broad while that of the other two species is not more than one-third longer than broad, greatly flattened and not curved upward.

Tibial characters again leave *Canthon* isolated. It bears but one spur and four longitudinal, crenate ridges, whereas the tibia of *Aphodius* and *Blobocerosoma* bears two spurs and several transverse ridges. The likeness of the latter two ends here: the ridges on the straight tibia of Aphodius number three and each bears a single row of spines; four unarmed transverse ridges cross the tibia of *Bolbocerosoma* which is it greatly bowed inwardly.

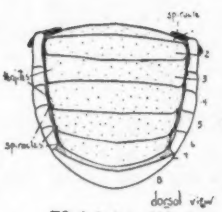
Parts	Canthon	Aphodius	Bolbocerosoma
Prothoracic intersegmentalia.	Intersegmentalia prominent.	Intersegmentalia prominent.	Intersegmentalia minute.
Prothoracic legs.	First tarsal segment protected by expanded tibia and exceeds the combined length of the next three. Paired erect setae are not found between the claiws.	First tarsal segment unprotected, shorter than the second and equal in length to the third and to the fourth. Two erect setae between the claws.	First tarsal segment unprotected, and equal in length to each of the next three. Paired erect setae are absent between the claws.
Meso and Metasterna.	Metaepimeron fails to touch the mesocoxal cavity. Mesoepimeron prolonged mesally reducing the anterior portion of the mesoeternum. Coxal cavities penetrate deeply into the metasternum.	Metaepimeron touches the mesocoxal cavity. Mesoepimeron not modified so as to restrict the anterior portion of the mesoeternum. Coxal cavities do not penetrate deeply into metasternum.	Metaepimeron fails to touch the mesocoxal cavity. Mesoepimeron prolonged mesally reducing the anterior portion of the mesosternum. Coxal cavities do not penetrate deeply into metasternum.
Mesotergum and Elytra.	Scutellum covered entirely when wings are closed.	Part of scutellum visible when wings are closed.	Part of scutellum visible when wings are closed.
Mesothoracic legs.	Coxae cylindrical widely separated Tibial spurs of unequal length, set on same level. Tarsomeres. compressed.	Coxae flattened, nearly touch mesally. Tibial spurs of nearly equal length. One set above the other. Tarsomeres not compressed.	Coxae flattened, touch mesally. Tibial spurs of nearly equal length. Tarsomeres not compressed.
Metathoracic legs.	Coxae imbedded over two abdominal tergites, hidingthem. Bear only one tibial spur. Tarsal segments compressed and the proximal one hardly longer than the next three. Lacks two erect setae between the claws.	Coxae compressed, not embedded, but conceal two abdominal tergites. Bear two tibial spurs. Tarsal segments not compressed, and the proximal one being at least twice as long as any of the next three. Bears two erect setae between the claws.	Coxae compressed, not embedded, but conceal four abdominal tergites. Tarsal segments not compressed and the proximal one being at least twice as long as any one of the next three. Lacks two erect setae between the claws.
Metathoracic wing.	Tegula present.	Tegula present.	Tegula absent.

VII

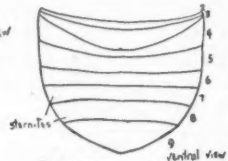


77 Canthon

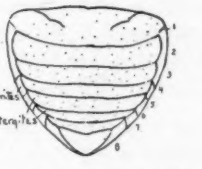
78 Canthon : Abdomen of Male



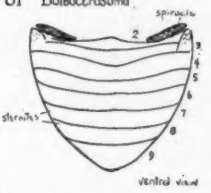
79 Aphodius : Abdomen



80 Aphodius : Abdomen

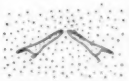


81 Bolbocerosoma



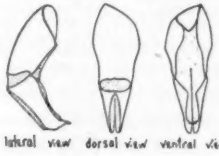
82 Bolbocerosoma : Female

83 Canthon : Female Genitalia

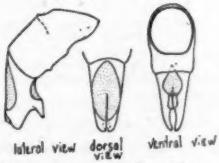


85 Bolbocerosoma Female Genitalia

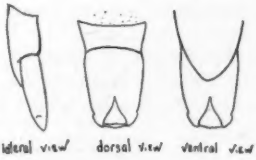
84 Aphodius : Female Genitalia



87 Aphodius . Male Genitalia



86 Canthon : Male Genitalia



88 Bolbocerosoma Male Genitalia

PLATE VII.

The tarsal segments of *Canthon* are compressed and the proximal one is barely longer than three distad of it. The proximal segment of the other two species is at least twice as long as any one of the three following it. Aphodius is distinct in bearing two setae between the claws.

Metathoracic Wing (Figs. 74, 75, 76): The metathoracic wings of *Canthon* and *Aphodius* bear tegulae; that of *Bolbocerosoma* is without. The anterior margin of the costa of *Canthon* bears setae on its apical half. None occur beyond the weak point at which the wing folds. In Aphodius these setae are shortened to form a sawlike edge. A few hairlike ones are found beyond the "joint" or weak point. This portion of the wing of *Bolbocerosoma* is similar. *Bolbocerosoma* stands alone in having a few fine setae on a vein which is labelled "second anal." It again stands alone in having but one radical branch whereas, *Canthon* and *Aphodius* have radius$_2$ and radius$_3$ present. *Canthon* is peculiar in showing a well-developed first anal vein and in having between radius$_3$ and media, many fine veins, *Bolbocerosoma* bears some thickening at this point which are not figured because of some uncertainty that they are veins.

Abdomen (Figs. 77, 79, 81): The abdomen of each species is as broad as long. In *Canthon* and *Aphodius*, it is terminally blunt; in *Bolbocerosoma* it terminates rather sharply. Eight tergites are present. In *Canthon* they are almost membranous except the last which is chitinous in the three species; in *Bolbocerosoma* almost as chitinous as its tergites; and in *Aphodius* somewhat intermediate in chitinization. The first tergite of *Canthon* is broader than any of those following and is not completely marked off by a suture from the second. The first tergite of *Bolbocerosoma* is almost incompletely marked off by a suture, but differs from *Canthon* in having only a mesal portion visible dorsally, being somewhat reduced. The first tergite of *Aphodius* is completely marked off and is narrow as compared with any of the following six, but not as narrow as the seventh. The pygidium or eighth tergite is chitinous, triangular, and exposed only in *Canthon* when the elytra are at rest.

The abdominal spiracles number seven pairs for each species and are found on the membrane connecting the sternites with the tergites. When the elytra are at rest, they are covered except for the peculiar first pair of *Bolbocerosoma*. The first spiracle on either side is narrowly oval and transverse. Its position for each of the three species is significant. It is very evidently dorsal in *Canthon;* in *Bolbocerosoma* it is very evidently ventral; while in *Aphodius* its position is intermediate but still to be seen in dorsal as well as lateral aspect.

The six remaining spiracles are small and circular in the three species. They are very plainly exposed in *Canthon*, but in *Bolbocerosoma* much manipulation is necessary in order to see them, for the tergites are expanded laterally covering them deeply. In *Aphodius* the condition is somewhat intermediate, but none of its spiracles are visible without some manipulation.

The sternites (Figs. 78, 80, 82) number eight for each species, and these, according to Hayes (1922), represent the second to the ninth, the first having become reduced. The second and third bend abruptly inward as a provision for the metathoracic coxae and are embedded partially between the metathorax and third stenite. They are not as heavily chitinized as those which are exposed. In *Canthon*, the ninth and last is deeply notched, so that the tip of the pygidium is exposed, the notch being greater for the male than for the female. In *Bolbocerosoma* this segment is triangular in the female, preventing a ventral view of any part of the pygidium, but for the male it is somewhat truncate showing a bit of the pygidium. In Aphodius there is no sexual difference evident and the pygidium is not to be seen in ventral aspect.

Parts	Canthon	Aphodius	Bolbocerosoma
Abdomen.	The eighth tergite exposed when the wings are closed. First abdominal spiracle dorsal in position. Sternites closely fused.	The eighth tergite covered when the wings are closed. First abdominal spiracle dorso-lateral. Tergites articulate freely.	The eighth tergite covered when the wings are closed. First abdominal spiracle vetral in position. Tergites articulate freely.

Female Genitalia (Figs. 83, 84, 85): Homologies seem not difficult to make. Paired chitinous plates occur on each side of the meson. Those of *Canthon* are one third as broad as long and are club-shaped; those of *Aphodius* are strap-like and twisted each approaching an S in shape; and those of *Bolbocerosoma* are somewhat triangular, half as wide as long at the broadcast point and sparsely setaceous.

Male Genitalia (Figs. 86, 87, 88): Without examination of a number of intermediate forms, it is not well to attempt to homologize the parts of the male genetalia of *Bolbocerosoma* (Fig. 88) with those of the other two species, which are very evidently similar. Possibly the distal segment is homologous with the distal segment of the other two. This part differs chiefly from the other two in being greatly depressed.

There can be no doubt about the homologies of the genitalia of *Canthon* and *Aphodius* (Figs. 86, 87). The basal pieces are homologous and also the distal pieces. These differences occur: The basal piece is caudally asymmetrical in *Aphodius* and the chitinous portion is not closed ventrally. In *Canthon* it is symmetrical and closed. A dorsal membranous area connects both pieces in *Aphodius;* in *Canthon* the entire connecting area is chitinous. In *Aphodius* the dorsal portion of the distal piece is membranous to its caudal end, in *Canthon* the membrane is limited caudally by a chitinous bar arising from the lateral chitinization. The ventral membrane of the same piece is terminated only at its distal end by a sharp terminal tooth arising from each lateral chitinization in *Aphodius;* in *Canthon* it is limited at about the middle by a similar tooth.

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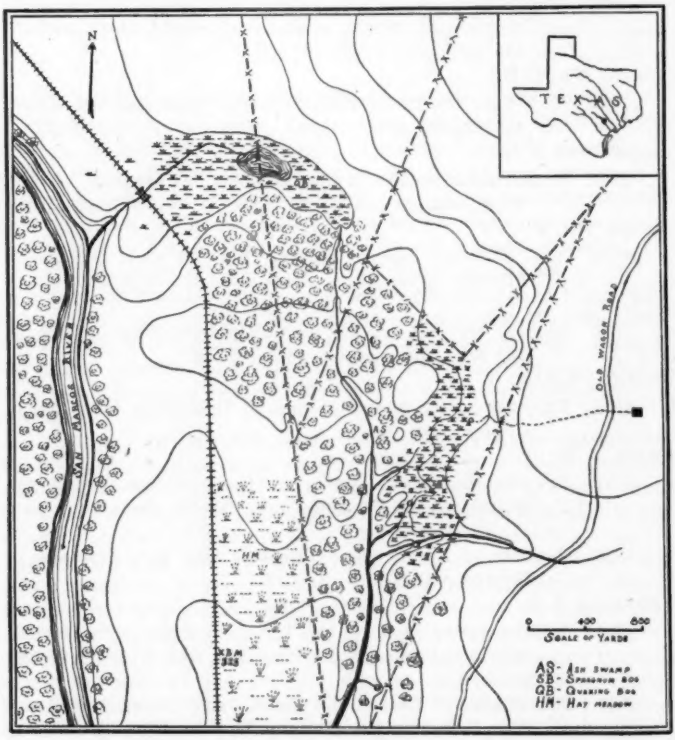

Sketch map of bog area.

TREND OF SUCCESSION IN A SOUTHERN BOG

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Situated within the coastal prairie of Texas and comprising a conspicuous part of the lowland vegetation of its particular locality is a bog whose uniqueness is due to its position relative to climate rather than to its importance as a marsh. Its ecologic position seems to have a bearing upon succession taking place within it as well as to provide extensions in the recorded distribution limits of a typically eastern flora. In all, the bog area is in decided contrast to the surrounding vegetation, for aside from scattered coastal marshes and a few east Texas lowland swamps, the vegetation of Texas bears a decidedly mesophytic stamp. Toward the western part of the state the species of plants are of more and more xeric types with the diminished rainfall. This tendency toward xerophytism is remarkably uniform over western Texas as a whole.

This characteristic of the vegetation of Texas was early recognized by Bray ('99-'06) and later confirmed by the descriptive work of Tharp ('26) in his study of the eastern half of the state. In river bottoms there is a recurrence of eastern types of plants, chiefly herbaceous forms. This is true even as far west as the Trans-Pecos Region, but nowhere has such an abundance of species been recorded in such an apparently stable unit of vegetation of such anomalous distribution as is found in the river bottoms of the San Marcos River in northern Gonzales County a few miles above the river's junction with the Guadalupe River.

A considerable part of the bog area occupies an ancient river flood plain, now far enough above the level of high water during flood periods to escape all but very slight inundation near the river channel proper. Because of the flood plain origin of the area, there is little difference in level except that due to secondary erosion, and this variation in level affords but partial drainage of the area through the overflow channels leading into the river. As a consequence, much of the water entering the area both by rainfall and through seepage is retained and thus helps to maintain the established bog conditions. Local influences enter here and there, and it is from observing the effect of these that the probable trend of succession here recorded has been studied.

VEGETATION UNITS IN THE BOG AREA

Work on the locality was distributed over four years and was undertaken primarily from a systematic standpoint. Plants were collected as much as possible in their seasonal aspects, and it was from a study of these, their growth forms, and from habitat data that attention was focused upon certain definite changes that were taking place during the period of collection.

Certain vegetation units have been separated from each other, chiefly on the basis of dominant species in combination with physiographic factors. Briefly they are as follows: The ash swamp, the sphagnum bog, the quaking bog, and the hay meadow. They will each be described in detail.

THE ASH SWAMP

From the accompanying map, it can be seen that this is the largest homogeneous unit of lowland vegetation. The ash swamp is an alluvial forest occupying an old river flood plain but extending up the adjacent sandstone slopes to a short distance. The soil consists of clay, sand, and dark organic matter and burns to a reddish mass with much the hardness and feel of brick. No soil except that of this particular unit of vegetation has this tendency to thus cohere and fuse.

There is a shallow drainage system of small interlacing channels within the bog. During a part of the year they contain no water except for brief periods after heavy rains. At other seasons they are full and overflowing. These seasonal variations in water table constitute an interesting problem in themselves. The natural contour of the bottoms is such that with the exception of the bogs proper, comparatively few parts serve as retention basins; and although the run-off is gradual, the effect of rain ponds because of their limited size is slight. Where such ponds exist the woody vegetation is reduced, which seems to indicate their already long existence. The three most important of them occurring in our area have been designated by circular enclosures on the map.

The periodicity of the water table presents an interesting phenomenon. The time of maximum inundation of the swamp area is during winter and early spring. This becomes less pronounced as the season progresses and reaches an approximate minimum during mid-summer. During late fall and early winter the rise of the water table can be readily observed by the increasing wetness

of the top layers of soil, which condition reaches a maximum at mid-winter. Because of the rough coincidence with changes in the development of the leafy canopy the theory that leaf transpiration plays an important part in reducing the ground water has been advanced several times by workers in the field. However, there is no evidence to substantiate this assumption. The importance of this periodicity lies in its effect upon successional sequence in the parts of the swamp where the most rapid changes are taking place.

In addition to comprising the largest part of the bog area, the ash swamp represents the largest single aggregation of ash trees of this species anywhere west of the east Texas river bottoms. Toward the eastern border of the wooded flood plain, contact is made with the sphagnum bog, which in turn meets the slope of the sand hills adjacent to it. On the west and also on the south the river terminates the vegetation except where cultivation has been practiced. It is near the southwestern corner of the flood plain that the hay meadow previously mentioned occurs. On the north, contact is made with the quaking bog.

Fraxinus pennsylvanica is the dominant species of the ash swamp except in marginal situations. Here grows a generous mixture of *Quercus macrocarpa, Quercus rubra,* and *Quercus shumardii.* These three along with scattered small ash trees grade into and give way to the sand hill dominants of *Quercus stellata, Quercus marilandica,* and *Carya sp.* On the other hand, where the sphagnum bog is intermediate in position between the ash swamp and the uplands, *Quercus macrocarpa* is the chief forest tree, mixed with numerous saplings of *Salix nigra* and *Populus deltoides.* The only tree of *Quercus alba* observed in the entire region of northern Gonzales County occurs here in this transition zone. In the more open parts of these marginal areas, occasional trees of *Fagara clava-herculis* and *Sapindus drummondii* are mixed with the common river bottom *Celtis mississippiensis.* Such trees as the last mentioned three exhibit a peculiarity of bark structure that appears to be due to the crowding effect of the other trees. Instead of the customary roughness, the bark in most instances resembles that of the beech in smoothness with but minor irregularities. The growth habit is also modified so that the trees are slender and tall instead of having the normal low spreading habit.

The understories are of two general classes. The first includes those lianas that reach the level of the arboreal canopy and include robust forms such as *Campsis radicans, Parthenocissus*

quinquefolia, Ampelopsis arborea, and *Ampelopsis cordata.* The others make up a distinct layer and include the smaller lianas and the characteristic undershrubs of the forest. *Smilax renifolia* and *Berchemia scandens* along with certain unimportant species are the more common of the smaller scandent forms and in many cases nearly cover the small trees in more open spots. Among the trees of this second system of layering are *Ilex vomitoria* and *Ilex decidua, Morella cerifera,* and *Ulmus alata.* Occasionally a third and lower layer of *Sabal glabra* and *Aesculus pavia* occurs. In some of the better lighted parts of the ash swamp occasional trees of *Crataegus texana, Rulac texana, Svida asperifolia, Sambucus canadensis,* and *Viburnum rufotomentosum* are to be found in the second system of layering. Of these *Crataegus* and *Sambucus* are practically the first to flower in the early spring and are conspicuous enough to deserve mention.

A possible fourth layer may be distinguished in the epiphytic plant of *Dendropogon usneoides,* commonly called Spanish Moss. This is of unusual abundance on the trees of the lowlands and rapidly disappears on the trees of the adjacent slopes, where it is replaced by the more xeric species, *Tillandsia recurvata.* The former species occurs on both ash and oak up to the tops of the lower trees. It is apparently terminated both by the light intensity and the drying effect of winds that sweep over the tops. On the other hand, unless removed by browsing animals, the epiphyte extends almost to the ground in many places. Thus, if we may properly speak of this plant as comprising a layer, we have one of unusually wide vertical distribution.

During the early spring before the leafy covering develops to any considerable extent, two types of ground vegetation exist. One is aquatic and depends upon the presence of the high water table and disappears simultaneously with the lowering of the water level. The other is terrestrial and the normal herbaceous covering composed of early maturing plants, most of which are perennials.

The aquatic species are few, *Callitriche heterophylla* and *Potamogeton lucens* being those most abundant. In addition, such mud loving plants as *Iris hexagona, Juncus effusus, Onosmodium bejariense,* and *Muricauda dracontium* skirt the borders of the drainage channels. The Iris is found scattered in several places, nowhere abundantly. *Muricauda* is even more widespread but scarcely more common. It is among the first plants to send up its leaves, later also producing the flowering spathes. The leaves soon

die, and upon the maturing of the fruit the stalks fall over, leaving the red berry-like fruits to be spread by birds and whatever means may afford.

Muricauda, Iris, Sanicula canadensis, Geum canadense, and *Amsonia amsonia* are the most common perennial spring herbs. These mature their activities by early summer. Among the common annuals are *Bowlesia septentrionalis, Cardamine arenicola* and *Cardamine pennsylvanica, Galium aparine, Poa annua, Myosotis virginica,* and *Senecio lobatus.*

By early summer, species of *Persicaria, Cardiospermum halicacabum,* and *Willugbaeya scandens* take complete possession of the border areas and such open spots as may exist. These marginal areas grade into comparatively broad flats of *Diodia teres* that lie between the ash swamp and the quaking bog on the north and the sphagnum bog on the east. In these interrupted transition zones, such woody plants as *Morella, Ilex* and *Baccharis sp.* may be found.

Under the trees the vegetation in summer is restricted to typical shade loving plants as *Heliotropium indicum, Saururus cernuus, Oplismenus setarius,* and *Polymnia uvedalia.* The fewness in numbers and the small size of some of these species contribute but little to the effectiveness of the ground cover. *Saururus* is more gregarious in the better lighted situations, while *Heliotropium* occurs here and there along the drainage channels.

THE SPHAGNUM BOG

The sphagnum bog is the smallest unit of the vegetation here considered. It lies east of the ash swamp in a narrow zone running north and south and is fed by seep water that in several places comes forth with sufficient volume to produce flowing springs. Considerable quantities of peaty material belonging to the decay of the older sphagnum moss and small amounts of sand make up the soil. Thus, even when the water table is low enough to allow surface dryness in the ash swamp, sufficient water is retained by the subsoil of the sphagnum bog to permit such plants as would perish by complete drying to persist. The sphagnum moss finds itself here at its known southwestern limit in the United States, as far as available published data is concerned. Prior to its discovery in the bogs here, the known limit was in the river bottoms of east Texas. Thus a few hundred miles extension of range is hereby added.

The several dominants are difficult to determine because of the decidedly seral nature of the bog. On practically all open wet sandy flats, *Monniera monniera* and *Hydrocotyle ranunculoides* form mats that are characteristic of the situation, exercising a degree of control so effective as to exclude practically all other plants. More centrally located are *Sagittaria falcata, Andropogon glomeratus* on minute hummocks of its own making, and *Typha latifolia.*

Boundary lines are nowhere sharp except where minor topographic conditions permit. In general there is more or less complete grading of herbaceous forms from sphagnum bog to ash swamp until excluded by light, and the woody species of the latter form a sinuous line where the two units make contact. Of these trees, *Salix nigra, Ilex decidua* and *Ilex vomitoria, Prunus mexicana, Morella cerifera,* and *Aesculus pavia* may be looked upon as indicative of the transition. *Morella* seems more tolerant of varying soil and light conditions and therefore forms the broader band included within the two units of vegetation.

Seasonal changes give a more varied floristic appearance in the sphagnum bog than is to be expected in the ash swamp. The prevernal period is one of winter rosettes and seedling plants. Active growth from perennial roots and rootstocks comes later in the season than does that of the seedlings of such species as *Chaerophyllum teinturieri, Cardamine arenicola, Commelina nudiflora, Persicaria hydropiperoides, Ptilimnium capillaceum, Poa annua,* and species of *Cyperus* and *Eleocharis.* The rosettes of *Samolus floribundus, Carduus muticus,* and *Cicuta maculata* begin development later in the season.

The first pronounced changes come during the latter part of February and early March. Among the first plants to bloom of the above mentioned species are *Cardamine, Chaerophyllum, Ptilimnium,* and *Commelina.* These are followed by *Ipomoea speciosa, Jussiaea suffruticosa, Monniera,* and *Sagittaria. Willugbaeya scandens* comes into flower at the end of the season along with the sedges.

With the coming of summer the greatest percentage of conspicuous flowers are in bloom, and of these *Jussiaea, Commelina,* and *Monniera* persist with additions of *Conoclinum coelestinum, Lobelia splendens, Carduus muticus, Helianthus strumosus,* and additional species of *Persicaria.* Most of these continue until fall with few changes.

THE QUAKING BOG

The quaking bog closely resembles the sphagnum bog, at the same time representing an apparently more mature stage. The substratum is also of high water retaining capacity and in addition to the decayed organic mass there is during the time of greater soil water a distinct layer of ooze, lacking in the sphagnum bog. It is the floating effect of the superimposed material that gives the bog its quaking nature during a part of the year. On the other hand, the quaking bog, because of its limited extent, is in no way comparable to those large bogs of the north, for it has no great depth, and during the dry period much of the quaking disappears. A pond of open water lies in the center, and in this the water, too, recedes periodically, leaving a mud bottom with its incidental vegetation until the next period of flooding.

Sedges exercise control with grasses as apparent invaders. The soil consists of much of this decomposed sedge material in addition to the remains of sphagnum which appears sparingly in the more sandy places. From the pond-like depression in the center, a shallow ill defined drainage channel carries the overflow water westward into the river.

Two species of *Eleocharis* exercise control. Of these, *Eleocharis interstincta* occupies the pond-like depression proper with the exception of the very center and terminates abruptly at the water level with a rapid change to *Eleocharis tortilis.*

From the center of the pond northward the following zones may be described:

100 foot zone of *Daubentonia longifolia* and *Eleocharis interstincta.*

120 foot zone of *Eleocharis tortilis.*

100 foot zone of *Morella, Ilex,* and *Baccharis.*

30 foot zone of *Pteridium aquilinum.*

From this point cultivation is begun and the nature and extent of the natural vegetation lost. From the center of the pond southward the zone of *Eleocharis tortilis* makes contact with a broad zone covered with *Diodia teres* in summer on which occur such woody species as *Ilex vomitoria* and *Ilex decidua, Salix nigra,* and *Morella cerifera.*

The seasonal changes present here the greatest riot of color. Winter rosettes are of the same species as found in the sphagnum bog. *Cicuta* is scarce and *Carduus muticus* has not been reported.

In the summer the bog is in its most colorful condition. *Bidens frondosa* and *Bidens nashii* begin to bloom and continue throughout the summer. *Conoclinum coelestinum, Pluchea camphorata, Isnardia palustris, Ludwigia glandulosa* and *Ludwigia alternifolia, Jussiaea suffruticosa* and *Jussiaea diffusa,* and *Rhexia mariana* add to the display. A single orchid, *Habenaria repens,* has been reported. During the fall most of these same species continue, and *Willugbaeya scandens* often completely covers low shrubs and small trees. Among the grasses, *Andropogon glomeratus* and *Andropogon virginicus* are conspicuous along with *Sporobolus buckleyi.*

A very interesting secondary sere is initiated in the pond-like basin during the dry period. Upon this bare area *Hemicarpha micrantha* and two grasses, *Eragrostis hypnoides* and *Paspalum sp.* establish themselves. Seed matures and sheds before the ground becomes flooded again.

Invaders are practically excluded in the sedge zone because of the density of the stand and unfavorable conditions for ecesis. The shade under the sedge cover is very dense as are also the mats of rhizomes. Both operate effectively to exclude invaders. The introduction of cattle has through injury of the sedge covering enabled *Salix, Fraxinus,* and *Populus* to establish themselves. Ring counts indicate that these invaders have been established for several seasons and seem capable of maintaining themselves successfully.

THE HAY MEADOW

This is a small unit much disturbed by mowing and apparently reduced in size by the cultivation of parts of it. Three grasses dominate. They are *Spartina gracilis, Paspalum glabratum,* and *Panicum virgatum.* The stand of these grasses is so dense that practically no other vegetation enters except a few plants of *Acuan illinoiensis.*

TREND OF SUCCESSION IN THE BOGS

The general trend of succession may proceed in three directions. The most direct and the one that seems the normal one is from sphagnum bog to ash swamp and from there to *Ilex-Myrica* and finally to the upland climax of *Quercus-Carya.* This is indicated by the effect of a winter and spring hydroperiod accompanied by practically dry soil on the partly silted-in margins

during late summer and fall. This dryness kills the sedge and sphagnum covering and creates a bare area suitable for ecesis of the ash seedlings. Such seedlings are not very abundant but are of various ages on these silted-in areas. The ash swamp is a stage of long duration, as can be determined by the large size of some of the ash trees found within it. In addition to these large trees, others of similar proportions mostly of *Populus* along with large specimens of *Quercus macrocarpa* and *Quercus shumardii* give every indication that this seral stage is one of already long existence.

Where rain washes cause rapid silting of portions of the sphagnum bog a succession follows that seems ultimately to result in the *Spartina-Paspalum-Panicum* meadow. This is also an almost static stage, for the density of the grass prevents woody species invading and from successfully competing. Where these silted-in areas of the sphagnum bog are flooded periodically by the rising water table during winter and spring, bare areas are produced that allow *Salix* and *Populus* to enter and be finally followed by *Fraxinus*. The crowding of the first invaders of woody species decimate the numbers until the distribution approaches in appearance that of the existing portions of the ash swamp. As the trees increase in size, only the tallest survive.

In the elevated parts of the grass meadow where the maximum hydroperiod is shorter and comes during the months of root dormancy, the grass responds by rapid growth. In its best expression, both *Panicum* and *Paspalum* reach a height somewhat above the head of an average sized man, while the *Spartina* rarely exceeds three feet at most. Mowing apparently has no further effect than that suggested above, of reducing the number of perennial herbs and making the exclusion of woody invaders complete. Close grazing works an elimination of the grasses and initiates a secondary sere characterized by the overgrazing indicators of *Dichrophyllum marginatum* and *Helenium tenuifolium*. This is contrasted with the sere initiated by cultivation and later abandonment. This latter begins with *Ipomoea trifida* and is followed for a number of years by *Iva ciliata* and *Ambrosia aptera*, and still later by woody invaders of *Salix, Populus,* and *Fraxinus,* which seems to indicate a return to the ash swamp conditions. The ash swamp, thus, seems to be the major seral stage preceding the climax and the one to which most other successful stages tend to go.

All three species of grasses yield to cultivation readily. *Spartina,* however, resists midsummer grazing better than either of the other two because of the unpalatable condition of the leaves. These early become sharp pointed and impalatable. The repeated injury to the rhizomes under the hoofs of the animals causes this grass to finally yield with the rest. Early spring grazing, on the other hand, effects all three alike. Heavy grazing in all cases prevents seed production and aids extermination through distruction of rhizomes either by starvation or mechanical injury. With the removal of the grasses, *Dichrophyllum* and *Helenium* enter.

Where the sphagnum bog receives no silt from rain washes and has but a brief winter hydroperiod, the succession normally goes to the *Eleocharis tortilis* stage. Because of the stabilizing effect of the sedge mats, the underlying organic ooze, composed chiefly of partly decayed sphagnum along with other plant remains, becomes covered with a more substantial covering. This forms a quacking bog with a semi-fluid substratum.

If, on the other hand, as in some portions of the bog, the maximum hydroperiod is during both winter and spring because of retention of a part of the water and is never followed by absolute soil dryness during the summer, the stage will be *Daubentonia longifolia* and *Eleocharis interstincta* of such abundance as to practically fill the pond-like depressions up to a depth of water of three feet. Through the acumulation of soil and debris brought in by rains and through the deposition of plant remains this stage will no doubt yield to that of *Eleocharis tortilis.*

Where silting continues slowly the succession goes gradually into *Sporobolus-Andropogon* associes, into which *Pteridium aquilinum* comes in the more compact and better drained soils. Such banks of fern show considerable invasion by *Ilex* and *Myrica* and give every indication of being in the direct successional sequence. If the silting takes place rapidly, as has been the case in some instances where an entire *Eleocharis* bog has been silted-in by rains, *Axonopus compressus* covers smooth flats, entirely devoid of ligneous vegetation. In fact, practically no invaders occur in this carpet grass stage. *Pteridium* tends to invade marginally and gives evidence of securely holding the ground thus gained by the creeping rhizomes. *Axonopus* is eliminated by too much shading, and the fern gradually pushes farther into the carpet grass flat.

Such instances of silting of the quaking bog, as just mentioned, must take place rapidly to have the effect observed. Information

from farmers of the adjoining region reveals that one of the carpet grass flats examined has been produced within the last forty years; and an old wagon road that now passes directly over it has been pointed out as following a more circuitous route before silting-in took place. Whatever the duration of these flats, the succession seems ultimately to go to *Pteridium*, then to *Ilex-Myrica*, and then to the upland climax.

The two directions of succession given above seem to be those normal to the quaking bog. Cattle, however, initiate conditions that show a trend toward the conditions of the ash swamp. Grazing itself has little effect upon the *Eleocharis* mat, for the stems are tough and difficult to get. The chief injury to the mat is due to the breaking of the cover by the animals' hoofs. Upon bare areas thus produced, seedlings of *Populus, Salix* and *Fraxinus* have become established in great numbers. Ring counts of the larger ones showed that the invaders were in their fourth growth season during the summer of 1928, and every evidence suggests permanency of these plants. Where such woody species enter and successfully compete, ash bog conditions will probably represent one stage of the sere leading to the upland climax.

With reference to biotic factors in the ash swamp itself, it is significant to note that although *Quercus shumardii* is repeatedly found as seedlings, those of *Quercus macrocarpa* are practically never encountered. This condition depends chiefly upon the activity of the squirrels, who seem to prefer the larger acorns of *Quercus macrocarpa* to those of *Quercus shumardii*. Within two weeks of the falling of the acorns, practically none are to be found. Those of *Quercus shumardii* are present in abundance. This almost complete destroying of the seed crop must ultimately tend to greatly reduce if not eliminate this oak, for with age and injury through other natural causes a certain number of these trees die each year. With the loss of the seed through squirrel activity no new individuals can become established.

NEW RANGE LIMITS FOR CERTAIN SPECIES

The taxonomic study of the plants of the region has revealed a number that are out of their reported range. Those not previously reported for Texas are here recorded. At present too little is known of the distribution of species within the state itself to make any comment concerning those species that have been pre-

viously reported for Texas but which have not been encountered this far west before. They are, consequently, omitted.

In making this list, Small ('13) has been used as the authority. This has, however, been supplemented in all cases by consulting the work of Coulter ('91-'94) and that of Wooton and Standley ('15). The species are listed in alphabetic order with the name of the state denoting the limit of southwestern distribution following.

Anchistea virginica (L.) Presl. Louisiana.
Bidens laevis (L.) B. S. P. Georgia.
Cardamine arenicola Britt. Tennessee.
Cardamine pennsylvanica Muhl. Missouri.
Erianthus compactus Nash. Tennessee.
Geum canadense Jacq. Missouri.
Habenaria repens Nutt. Louisiana.
Helianthus strumosus L. Arkansas.
Monarda fistulosa L. Louisiana.
Lorinseria areolata (L.) Presl. Louisiana.
Pieris mariana (L.) B. & H. Arkansas.
Panicum joorii Vasey. Louisiana.
Persicaria hirsuta (Walt.) Small. Georgia.
Phalaris angusta Nees. Louisiana.
Tradescantia brevicaulis Raf. Missouri.
Xyris caroliniana Walt. Louisiana.

SUMMARY

1. The bog vegetation is surrounded by a vegetation of a decidedly xeric nature and is isolated by wide and impassable barriers from vegetation of a similar nature.

2. The ash swamp presents the densest stand of ash trees found anywhere within the state of Texas.

3. The bog conditions as a whole present an edaphic climax that nevertheless shows definite successional tendencies.

4. The normal succession appears to be from sphagnum bog to ash swamp, where there is an early summer hydroperiod and fall drought. The succession tends to end in the upland climax.

5. Silting of the sphagnum bog allows meadow grasses to come in and thus temporarily diverts the succession into a moist meadow.

6. A short winter hydroperiod favors the formation of miniature quacking bogs on areas formerly occupied by sphagnum bogs, due to a semi-floating mat of sedge. Flooding to a greater degree causes a temporary hydrosere that returns finally to the sedge mat condition. The normal succession goes to *Ilex-Myrica*, as a final stage before the invasion of upland dominants. Silting produces minor changes within the sere itself.

7. Cattle by breaking the sedge mat favor the invasion of ash, cottonwood, and willow and divert the succession into the ash swamp.

8. Minor biotic factors indicate that the suppression of *Quercus macrocarpa* by the destroying of seed will lead to the final elimination of this species.

9. The published distribution of a number of species found in the bog area is here extended.

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AN INVESTIGATION OF THE METHODS OF PREPARING AND MOUNTING INSECTS FOR PERMANENT PRESERVATION*

FRED O. DODD

I. INTRODUCTORY

Insect collections are valuable for reference and research, for teaching and for exhibition. There can be no distinct groupings into these classes except by personal opinion, the differentiation between reference and research being perhaps the most difficult. Certain institutions set apart in special collections a limited number of specimens that are of special significance and the bulk of their specimens is included in a larger collection. These smaller collections are often held inaccessible to persons not actually engaged in their preparation while the larger ones are available for study or reference.

Specimens are exhibited for various reasons and such groups of individuals comprise an exhibit collection. It may contain a varying number of specimens depending upon its purpose.

The collection to be used in teaching varies, too. It is often quite incomplete when compared with a collection of the first group because of the fact that representative specimens are most commonly used in teaching.

Regardless of its ultimate use a collection should be properly prepared, mounted and labeled if it is to render its greatest usefulness. The increase in interest in Entomology has brought a decided increase in collection and many private collections have been and are being built up. Many specimens in these collections would, if properly mounted, throw light upon some entomological problems that are quite insufficiently solved now. It is with this in mind that this paper has been prepared and it is the hope of the author that it may be a step toward the betterment of general entomological technique. An effort has been made to bring together practical methods of preparing and mounting insects with special reference to the permanency of the preservation.

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II. METHODS OF KILLING INSECTS.

In killing insects the agents employed must act quickly. This is necessary to prevent specimens damaging themselves or others in the same container in their efforts to escape confinement. The manner of killing, therefore, is closely related to the methods of mounting and the purpose for which specimens may subsequently be used. Many insects must be kept free from surface moisture if proper mounting methods are to be employed and killing agents that cause hardening and contraction of the muscles or undue propulsion of cervical organs should not be used (see p. 301). With special groups certain added precautions should be taken and collectors should make an effort to learn the use for which their specimens are intended in order that they can supply material best suited for that particular purpose. Commercial concerns may find it advisable to furnish their collectors with materials and instruction and to refuse to accept specimens in other than the specified condition while individuals who mount their own material find practically no problem with killing methods.

Cyanide is the most widely used killing agent. Salts of potassium, sodium and calcium are available in rock or granulated form. The salts of calcium are not stable and are not practical for use in cyanide bottles and potassium cyanide is considered superior to sodium for killing insects. Cyanide bottles are prepared in various ways, three of the most practical of which will be discussed here: (1) place a liberal amount of cyanide in the bottom of a glass vial or container of convenient size and cover with a filler composed of dry sawdust, cotton or plaster of Paris. Then add a layer of freshly mixed plaster of Paris paste (plaster of Paris and water) and stand aside uncorked until dry. Before using the sides should be scraped free from paste; (2) a second method is similar to the first. A disc of porous sheet cork is substituted for the plaster of Paris paste and is superior to the first method in ease of renewal and cleanliness. The plaster of Paris has a tendency to rub off when it becomes damp; (3) the charged cork method is superior to both of the above if the cork used is large enough to admit the use of a sufficient amount of cyanide. The cyanide is placed in a small vial or "cell" as it is called and

inserted into a hole bored into the cork. The gas penetrates the cotton used to retain the cyanide. Bottles so made have distinct advantages: (1) specimens need not be transferred to other containers after death—the cork can be traded for that of another vial or bottle and (2) the bottles can be cleaned more easily after a period of collecting.

The disadvantages of cyanide as a killing agent can in most cases be traced to negligence on the part of the collector. Salts of cyanide are hygroscopic and the moisture that collects in the bottle is quite objectionable. This condensation can be prevented by use of blotting paper or other absorbent paper. This paper can be renewed when necessary. The yellow colors of some Hymenoptera, Lepidoptera, and Diptera turn reddish when exposed to cyanide too long. Such specimens should be removed soon after death. Specimens often become dirty when killed in cyanide bottles. Care in excluding dirt particles or dirty specimens removes this objection almost completely altho the careful collector finds the time used in cleaning his collecting bottles well spent. Lepidoptera and bees should not be killed in the same bottle with other insects as the scales from the wings of the former are easily dislodged and are extremely hard to remove from other specimens and pollen from bees raises a similar objection. In no case should larvae be killed in a cyanide bottle with other forms.

Hydrocyanic acid gas which is the active killing agent of cyanides is one of the most deadly gases known. Its action upon insects is not definitely known, but the fact that forms that respire rapidly are killed more quickly than other forms whose rate of respiration is much slower indicates that the effect is upon the respiratory system, probably producing both suffocation and paralysis. There is little danger from cyanide if handled properly although small amounts produce quick death to man and small animals and if left exposed to the atmosphere in a closed room may generate enough gas to produce death when the room is again entered. Too great precautions cannot be taken in handling it.

Alcohol has been used as a killing agent. Insects are dropped into weaker alcohol—usually 50 per cent— and after death the specimens are transferred to higher percentages. Preservation is accomplished at 70 per cent altho many workers prefer to use 80-95 per cent. Ethyl alcohol is the most satisfactory form for use as a killing agent, but it is hard to procure and cannot be carried about with safety even though it is for scientific purposes. When

collection is being done for commercial concerns good alcohol so treated as to be unfit for human consumption may be supplied, although there are few instances where alcohol is a very satisfactory killing agent. Its powers of pentration are too weak and because of its power as a dehydrating agent water is drawn from the body of the specimen faster than it is replaced by alcohol and shrinking from unequal pressure results. The outer tissues are hardened in this abnormal position and poorly shaped specimens are often obtained by killing in alcohol. Jackson ('07) has obtained satisfactory results with killing Thysanoptera in boiling absolute alcohol although heat is probably a great factor as we shall see in the next paragraph.

Hot water has a very definite place as a killing agent. It is especially good for soft-bodied forms and is probably the best known means of killing larvae and pupae. Kelsheimer ('28) lists the following advantages: "(1) it kills bacteria and prevents discoloration; (2) it coagulates proteins; (3) it straightens and preserves body form; and (4) leaf feeding forms lose less green coloring matter when later preserved in alcohol." The water should not be boiling vigorously. Tothill ('19) recommends that water at a temperature of 80°-90° C. be poured over the specimens. Equally good results may be obtained by pouring the water on the specimens or dropping them into it. They should be left in the water from one to five minutes depending upon the species. The time for a particular species must be determined by each collector. Specimens sometimes shrink if removed from the water too quickly or air spaces occur under the cuticle if heated too long or too vigorously, but these disadvantages can be overcome by careful work. Specimens that have a tendency to shrink when dropped into hot water may be killed by placing them in cold water and gradually heating until death occurs. This practice is not advisable because death does not occur suddenly enough especially for histological purposes.

Etheric oils—chiefly ether, chloroform and benzene—are often used as killing agents. They kill rapidly and specimens remain relatively cleaner than with other methods although the muscles become drawn and hardened which renders setting or spreading of wings quite difficult in most cases. The heads of insects such as Diptera and Hymenoptera often drop off because of undue propulsion of some organs in the cervical region. Specimens may revive after apparent death and care must be taken

to prevent such occurrences. Some workers prefer to inject ether or chloroform into the thorax of large moths and butterflies and the most practical use of etheric oils is probably the quieting of larger forms to prevent injury in their efforts to escape from the cyanide bottle before death.

III. FIXATION OF INSECT SPECIMENS.

"Fixation usually infers two things: rapid killing of the organism to retain its form and hardening to such a degree that it will withstand the effects of reagents with which it may subsequently be treated without change in form." (Lee, 1928, page 2.) After fixation with some process known as a fixing agent the specimen should in most cases be washed before final preservation.

Various combinations of alcohol and other substances have been used as fixing agents. One of the most widely used and best recommended fixers is Bouins Picro Formol. It is made under the formula—

Picric acid (Saturated Aqueous Solution)....	75 parts
Formalin	25 parts
Glacial acetic acid.....	5 parts

This must be washed out with 70 per cent alcohol after fixation for 12-24 hours, the optimum being about 18. Warm alcohol hastens the washing process considerably. According to Lee ('28), 1 part of picric acid dissolves in 86 parts of water at 15°C. It is more soluble in warm water.

Another picric acid combination known as picrosulfuric acid is recommended as a good fixer where it is necessary to penetrate chitin. Lee recommends its use for Orthoptera and gives the formula—

Distilled water	100 vol.
Sulfuric acid	2 vol.
Picric acid	Saturation

The usual procedure is to dilute this stock solution with three times its volume of water. This must be washed out with warm 70 per cent alcohol.

Ble's solution is recommended especially for embryological purposes and has the advantage over other fixers that the specimens need not be transferred to other preservatives. It is not stable and should not be used as a fixer after two weeks, altho it remains perfectly good as a preservative after that time. A stock solution

of 90 cc. 70 per cent alcohol and 3 cc. of glacial acetic acid should be made up to each 93 cc. of which 7 cc. of formalin should be added when one is ready to use it. The author has found this very good for the preservation of eggs, larvae and pupae of honey bees and some other soft-bodied forms.

Similar to, but stronger than Ble's solution, is one known as Carl's solution. Fixation is more rapid and overfixation begins after 24 hours. Specimens should be transferred to other preservatives. Washing is not necessary. The formula is—

Absolute alcohol	15 parts
Formalin	6 parts
Glacial acetic acid	2 parts
Distilled water	30 parts

Rawlin's solution is quite similar to the above two and is recommended as a good process by which to retain colors in stems, leaves and fruits of plants. The author has had little success with this fluid in fixing insects. The formula is—

Alcohol 70%	100 cc.
Formalin	2 cc.
Glacial acetic acid	5 cc.

Acetic alcohol is one of the most penetrating and quickly fixing reagents known and the two following formulae are recommended: Carnoy's Acetic Alcohol—

1.	Absolute alcohol	3 parts
	Glacial acetic acid	1 part
2.	Absolute alcohol	6 parts
	Glacial acetic acid	1 part
	Chloroform	3 parts

The addition of chloroform, according to Lee, hastens the reaction and is recommended where extremely rapid fixation is desired.

Kelsheimer ('28) has used uranium nitrate with promising results in preparation of egg masses of the European corn borer for the museum. He fixes for 2-5 days and transfers to alcohol. The formula is—

Uranium nitrate	1.5 gr.
Ethyl alcohol (95%)	90 cc.
Formalin	5 cc.
Glacial acetic acid	2.5 cc.
Glycerine	2.5 cc.
Copper chloride	5 gr.

Alcohol alone is recommended by Tillyard ('26) and Kelsheimer ('28). Tillyard also recommends Formalin 1 part to 10 parts of water, but classes both formalin and alcohol second to Ble's solution. Kelsheimer uses boiling 80 per cent alcohol as a fixative for white eggs to be preserved on the green leaves upon which they were deposited.

Kingsbury and Johannsen ('27) claim that 10 per cent formalin is a fair fixer satisfactory for gross study and museum preparation. They say that it is preferable to use formalin in connection with other chemicals. They also say that 95 per cent alcohol answers admirably for most histological study, fixing well, hardening and likewise dehydrating. In Lee ('28) we find an opposing view. Alcohol is said to be a fair dehydrating agent, but far less satisfactory as a fixer. Lee's contention is that no single substance or chemical fulfills all the requirements of a fixer and that alcohol is seriously lacking, especially for histological preparations.

Kelsheimer and others recommend that larger forms should be injected with formalin or some other fixing solution immediately after death or that death be produced in that manner. Very good results have been obtained in preservation of forms for study of internal anatomy in this way.

IV. Methods of Mounting Insect Specimens.

When the subject of mounting insect specimens is mentioned one thinks first of some use of pins as this is probably the most widely used method. There are several other methods, the discussion of which will follow in succeeding paragraphs. Many kinds of pins have been used by workers ranging from the short nickeled pins of German manufacture, to the black "Japanned" or "enameled" pins in use by workers of today. These earlier pins were nickled or tinned and were about the size of the ordinary dress pin. They were not very satisfactory because of a tendency to rust easily, and verdigris (see p. 323) was very common. They corroded when used in mounting practically all insects. Later workers used a longer pin and various sizes began to be used very soon. The efforts to eliminate verdigris brought about the manufacture of the japanned or enameled pin by a German concern. This was later taken up by American manufacturers with various claims for superiority of product. Pins of both German and American manufacture are available at supply houses at a nominal

cost and verdigris has been materially reduced by their use. American steel pins are also available, but they have a tendency to rust easily and are therefore not as satisfactory as japanned pins.

Very early, there was a tendency to use some form of what Tillyard ('26) calls double mounting. Various kinds of wire were used as substitutes for pins and a German concern produced a very fine pin known as the minutien-nadeln pin in two styles. One was made by pointing a straight piece of silver wire for entrance into both the insect and the secondary mounting structure and the other was known as the elbow pin. It was pointed on one end and bent so as to lie parallel to a larger pin passed through a coil in its opposite end. Such pins are in common usage by some modern workers for very minute insects.

Perhaps the most common method of mounting very minute insects is on points—triangular strips of paper or mica supported at their bases by No. 2 and No. 3 pins. There are many modifications of this method. Mica was perhaps first used because of its transparency. The specimens could be viewed from the under side even though glued to a strip of mica. Strips of blue paper were pasted on the mica to reduce the glare and afford a possible place to enter a small amount of data or a number. Mica has given way to some use of cardboard in most instances. Heat has a lesser effect upon the paper and curling is not experienced. These points may be cut from cardboard with a pair of scissors by ruling a series of triangles 3mm. wide and 7 mm. high, or they may be made with a specially constructed punch. If a good punch is at hand nice points can be made, but if the punch fits loosely the points may have an objectionable fringe on one side. Glue, shellac, or some specially prepared adhesive may be used to mount the specimens on these points. Here again opinions vary and about the only point of agreement is that the specimens should be mounted so that when the point extends to the left of the pin the head of the specimen should extend forward. Some workers prefer to use very fine points, others more blunt points in their efforts to leave the greater part of the under side of the thorax exposed. Some prefer to mount two specimens on one point; one on its ventral and the other on its dorsal side. Dr. Frison in the Illinois State Natural History Survey uses double points to mount elongated forms, such as May flies. Gelatin capsules have been used but they become hard and brittle after a few years and specimens cannot be studied without removal from them. The pin is

usually passed through the capsule and cap after the latter has been slipped on.

Materials used for supporting structures used in double mounting have been varied indeed. Small cubes of corks are most common, while pith, soft wood, certain fungi and other materials are encountered.

For larger specimens the methods of pinning are not so diverse. Earlier collections were pinned low on the pin but this practice is no longer followed. Specimens are placed near the top of the pins. The exact position is still a controversial matter, but the main considerations are that the insects should be placed at such a height on the pin that they will not be injured when the top of the pin is grasped by the fingers in handling the specimen and that all specimens are all arranged at the same height on the pins. In general, an insect should be pinned through the thorax along the median line, altho Coleoptera provide a marked exception to this rule. They should be pinned thru the anterior portion of the right elytron. Hemiptera should be pinned through the center of the scutellum. There is a general tendency to slant the pin slightly forward when inserting it in the body so as to include two segments giving greater strength to the body and giving a slight tilt to the specimen. Opinion differs in this regard, too, and the essential thing is that one should be consistent in which ever method he follows. Older workers carefully spread the legs of specimens, but this practice is not so strongly adhered to now. The tendency is to allow the legs to double up under the bodies to conserve space and prevent damage in handling. Care should be taken, however, to see that structural characteristics of the under side are not obscured by the legs. In groups where the mouth parts serve as characters for classification, it is well to see that they are visible while they are still movable. This often saves time in relaxing later.

It is advisable to spread the wings of certain insects in order to provide for visibility of certain characters for use in identification and to add beauty and uniformity to the pinned collection. Spreading boards have been devised to save time in this operation and variously modified types are available at moderate cost at supply houses. Rather simple boards may be constructed and directions for making such boards may be found in Banks "Collecting and Preserving Insects," U. S. National Museum, Bull. 67, page 58. Glass plates may serve as spreading boards. Place two

glass plates side by side leaving a crack just wide enough to admit the body of the insect. Place the insect in position and after spreading the wings of each side to the desired position use a smaller glass plate to hold them in place. This method is especially suitable for spreading Lepidoptera destined for the riker mount where there is to be no pin in the thorax.

The wings of both sides of Lepidoptera should be spread and only those of the right side of Orthoptera. The other pair should remain as indications of the position taken at rest.

The apparatus used in pinning insects is not necessarily elaborate. Two pairs of forceps, one for picking up small insects and the other for setting pins; a pair of scissors; a spreading board; some strips of paper; some points; and a supply of variously sized insect pins are all that are absolutely necessary. A pinning block is quite handy for getting specimens at the same level on the pin and in placing labels at varying heights. In absence of a pinning block a small cardboard box is a satisfactory substitute and many workers, especially in the field, use the lapels of their coats when pushing the pin through the specimens.

There are many insects or insect forms for which pinning is a very unsatisfactory method of mounting. Some of these can be mounted in stoppered glass containers in some preserving fluid or in some instances as dry mounts. Materials used as stoppers include cork, rubber and glass. Cotton may be used in temporary mounts, where the specimens are not completely dry. Cork is satisfactory as a stopper provided a good grade is used. It is easily available and is fairly economical in price. Evaporation is a great factor when cork is used and periodic examinations should be made of all containers to replenish the evaporated preservative. Rubber stoppers reduce the evaporation to a marked degree although they are quite expensive and when in contact with alcohol, sulfur crystals often form and become lodged on the specimens. This can be prevented to a marked degree by soaking the stopper in hot water for some time prior to use. Rubber stoppers especially should have a small insect pin inserted along their sides to allow for the escape of air or liquid displaced by them. When the stopper has been inserted to the desired position the pin should be withdrawn. Stoppers so inserted are less likely to "pop-out" with temperature changes than those inserted in other ways.

Vials are the most common perhaps of stoppered containers and are chiefly of three kinds: homopathic, shell and ring vials.

They are obtainable in various sizes and are useful in many ways in preservation. For specimens not in constant use the vials may be corked and dipped into paraffine wax as an aid in the prevention of evaporation. If properly done this method is quite satisfactory.

Bottles are used similarly to vials, but have the advantages of more sturdy construction and greater size. Both bottles and vials are useful in collecting and museum display work.

Mason and museum jars are other forms of stoppered containers. The Mason jars have screw or spring clamp lids which fit down tightly over rubber rings to reduce evaporation to a minimum. Even then it is necessary to make periodic examinations of materials mounted in them to replenish preservative material where necessary. They are of greatest value to the entomologist for storing his duplicate material in bulk and for storing small vials to reduce evaporation. Biological supply houses find them useful and various sizes to suit particular needs are obtainable. Museum jars are useful in temporary display of specimens, but evaporation is too great from them. There is a small hole in the lid of each that is supposed to take care of pressure changes to prevent breakage and this allows too much evaporation. Various waxes have been used to seal them and murrayite, an adhesive insoluble in alcohol or water, promises great usefulness in preventing this evaporation. Ordinary sealing wax is soluble in alcohol after a time.

Tubes and vials are quite similar in their adaptation. Tubes are usually longer and the ends are rounded which makes it hard to stand them anywhere for display. Various attempts have been made to include alcoholic tubes with the regular pinned collection and special blocks have been devised with spring catches for holding these tubes. Comstock devised a square bent neck vial that was used somewhat. In any case where stoppers are used a great deal of grief comes from evaporation and the stoppers sometimes come out allowing the liquid to run over the box. The Illinois State Natural History Survey made up a collection of insects a number of years ago and sent them to high schools. These included some alcoholic mounts that were sealed in a flame by Dr. R. D. Glasgow, then of the University of Illinois. These were satisfactory for their purpose but it is doubtful whether it is advisable to include alcoholic and pinned specimens in the same box.

Elaborate apparatus is not necessary for making stoppered glass mounts. Forceps, pins, needles, stoppers, preservatives and labels are about all that are necessary.

Hermetically sealed tubes make very satisfactory and attractive insect mounts. The specimens are placed inside, secured in some way to prevent damage in handling, and labeled and sealed. A similar method was in use in 1887 by Dr. H. Dewitz in Germany. He mounted the larvae of Microlepidoptera in very small tubes which he made from long tubing and sealed by use of an alcohol spirit lamp. The finished tubes were mounted in a hole in a cork and pinned with the related specimens. There was scattered use of sealed tubes from then until about 1910 when Dr. R. D. Glasgow began to develop the method at the University of Illinois. Some material was sealed for the State Natural History Survey and soon attention was directed to the department collection for class use. This work has progressed and it has been the privilege of the author to work with Dr. Glasgow and to carry on the work after he accepted a position in New York. In personal correspondence with Dr. R. K. Nabours at Kansas State College the information was received that grouse-locusts sealed in this manner about 15 years ago are in good condition. The method in use at Kansas is not so elaborate as at Illinois according to Dr. Nabours.

This method admits a wide range of specimens and a variety of ways of mounting each. Both dry and liquid preservations may be used and one can use his own initiative in deciding upon the method to follow. One somewhat skilled in glass working can modify the general methods considerably as glass supports are very neat and serviceable. Certain insects because of large size or other reasons need not be held by special supports. In many cases where no particular structural character is to be sought in later study there is no particular value in the extra labor involved of putting the specimens on supports. Larvae for the most part should be supported in some way while many adult specimens make much more serviceable mounts if supported in a certain position. Pins are used to a limited extent in hermetically sealed tubes. They may be bent before or after the insect has been placed upon them and then stuck into a cork triangle or fused to a glass rod in such a manner that the specimens assume the desired position in the tube. The cork triangle method is inferior to that of the glass rod. The pins become loosened in the cork and the triangle sometimes

slips leaving the specimen in an unsightly position in the tube. In fact, the use of pins in the glass tube method is not so satisfactory. There is too much tendency for specimens to slip off or turn and assume positions which make their study impossible. If pins are used they should be fused to a glass rod around which cotton has been wrapped to form a neat plug (see p. 311). The pin and rod should both be heated and the pin thrust into the end of the rod while both are still hot. If the enamel has been burned off, the pin will fuse with the glass and a permanent mount will result. This cannot slip sidewise as the cotton plug, properly rolled, prevents that and a shock great enough to break the glass rod would probably break the tube also. This method furnishes a means of transferring valuable pinned specimens to tubes where the damage from pests is impossible.

Glass rods alone form a very important group of mounting structures. Small solid rods ranging from about 5 mm. to 8 or 10 mm. in size are most convenient. These rods should be cut into convenient lengths and placed in a box for use later. For some forms a straight rod is used. This is made by heating a short section of the rod in the flame of a blast lamp (see p. 313) and drawing out to the desired thickness. The rod may be pointed for insertion into the specimen by placing in the flame at the point where it is desired to cut it off and drawing out rapidly. Bent rods are made in much the same way except that there is a right angle bend made in the glass rod before pointing it. Rods with double points are useful in supporting long and weak specimens, whose form makes it impractical to use the straight rod. These rods are made by welding a piece of glass rod to the bend made for the first lateral point. A second point is now made as was the first one.

Mica plates, opaque glass, cardboard and other materials have been used in mounting various insects. They are cut to fit the inside of the tube and the specimen is glued to them. Life cycles have been mounted in this same manner.

When liquid preservatives are used it is necessary to leave a small amount of air space to prevent changes in temperature from breaking the tube. This air bubble slips past the cotton plus that holds the label and specimen in place and interferes with the visibility of the specimen. In most instances it is impossible to remove the bubble through the plug and provision for its removal must be made while the tube is in process. This is best accom-

plished by a valve around which the cotton is wrapped to hold it in position. Glass rod supports may be welded to the large end of the valve when necessary. These valves are made by taking a piece of glass tubing about one-half the diameter of the tube to be sealed and cutting it into pieces about two inches in length. With the blast lamp adjusted to a fine and intense flame, rotate the tube in it at its center until it begins to melt. Remove from the flame and draw out rapidly yet carefully enough that the center of the drawn portion corresponds with the center of the tube until the drawn portion is slightly less than half the diameter of the original tube. With a knife or sharp file scratch the drawn portion at its center and break. Thus two valves have been made with one operation.

The cotton plug mentioned above serves a double purpose. It holds the label and the specimen support. It is necessary, therefore, that it be so constructed that it will not have side motion. The plug is made from a strip of absorbent cotton. It may be medicated or fumigated but one or the other should be used to prevent the introduction of insect enemies that may harbor in untreated cotton. A strip of convenient length about 3/16 of an inch thick and slightly narrower than the label to be used should be torn from the roll. With the fingers of both hands gently pull the cotton sidewise being careful not to tear it completely. When this is done roll the edges in toward the center until the width of the resulting strip is just that of the label. If no support or valve is to be used, roll a loose yet firm plug that will fit snugly inside the tube. If a valve or support is to be used, place a drop of glue on the support and roll the cotton around it until it fits snugly inside the tube after the label has been wrapped around it. If these operations have been carefully done there will be no loose edges of cotton sticking out from under the label and the plug will strike the glass with even pressure at each end thus preventing any side motion from shocks in handling.

For special mounting of some larvae and other elongate forms a constricted end tube is sometimes used. This mount is made by rotating a tube in a wide hot flame and gradually and carefully pulling out until the desired size is reached. This must be carefully done to insure the center being in line with the center of the larger tube and to maintain an even thickness in the drawn portion. Scratch the drawn portion at a desired point and break. Then thrust into the flame again and re-blow a new end on the

constricted part. After cooling place the specimen in position, add preservative and label and seal.

The difficulty is often experienced that insects fall from their supports after varying lengths of time. This may be prevented in a number of ways. With dry mounts ordinary glue is usually satisfactory. The muscles of insects contract and set after death and advantage may be taken of this fact to insert the supports before they have set. Thus the tissues set around the support and there is slight chance for their falling off. Slight heating at the point of entrance of the support often helps in this same way. For liquid mounts murrayite or some other adhesive insoluble in the preservative used should be employed. The author has had satisfactory results with celloidin as an agent for holding the eggs of aphids on bark. The eggs are coated with celloidin and the piece of bark dropped in 70 per cent alcohol before the celloidin has had a chance to harden. The visibility is not impaired in any degree and the eggs remain on the bark in life-like position. This method could be adapted to other things with equally good results.

There are no hard and fast rules governing the size and intensity of flame to be used in sealing tubes. It should be wide and intense enough that the glass can be drawn out without leaving a square shoulder next to the plug. However, it should not be heated in such a manner that the shoulder breaks off when cool. The tube should be held in such a position that it can be freely rotated in the flame until it almost closes off with molten glass. Then remove from the flame and draw out in such a manner that the drawn portion will remain at the center and its diameter will be about 2 mm. When cool break and while rotating in a vertical position close off the opening with a needle point flame. This method is the same for the liquid mount except that the preservative is usually inflammable and a certain amount of extra care is necessary to prevent breakage. The last process is usually the hardest. The preservative is close to the end of the tube and being very volatile generates gas very rapidly. This pressure causes bubbles in the molten glass and quite often causes the tube to break with explosive violence. A few trials will show the operator when to remove the tip from the flame to prevent this bubble burst. It may be said in general that it should be removed just as the molten glass begins to close over the opening.

The apparatus necessary for making hermetically sealed tubes is rather complicated. In the first place three kinds of glass are necessary. Soft glass tubes with regular ends sold under the names of ligature or culture tubes should be on hand in various sizes to accomodate any size of insect specimen. Various lengths of soft glass tubing for making valves should be on hand and a supply of variously sized solid glass rods should be available.

The blast lamp is quite important. On its ease and fineness of adjustment depend some of the finer points of the actual sealing operation. It should be capable of adjustment from a fine needle flame to a wide intense flame for heating large tubing. The Massachusetts Institute of Technology pattern has three interchangeable burner tips with which the range of flame is very satisfactory. A supply of oxygen should be available for use when sealing very large tubes and should be attached to the compressed air line.

A glass cutter is quite essential to economy of time in producing valves and other glass apparatus. A satisfactory electric cutter is in use in the laboratory at the University of Illinois. The cutting unit is a piece of No. 22 gauge chromel wire attached to the regular 110 watt circuit. There is a resistance unit composed of a salt solution (10 gr. salt to 1000 cc. water) through which the current must pass. A ring is made in the chromel wire to fit snugly around the tube at a point where a scratch has been made by a file or knife. When the current is turned on by a convenient switch held in the hand the wire becomes hot quite rapidly and the glass breaks squarely at the scratch. If the heating occurs rapidly enough this apparatus gives satisfactory results with glass of ordinary thickness. Too slow heating melts the glass and does not break it squarely.

For short tubes provision must be made to prevent burning of the hands while sealing. Cork is a good heat insulator and is quite satisfactory. A triangular trench is made in one side of a cork to allow for the escape of gases generated by heating and the tube may be turned by turning the cork. The author has used a double cork which is fastened together with staples made from insect pins. This affords a round surface to hold while turning and prevents occasional burning when the gas ignites at the end of the tube.

Push rods are necessary to insert the specimen into the tube to its proper position. Glass tubing just small enough to enter

the tube being sealed is best since equal pressure is exerted on all points of the circumference of the label and it remains straight.

Various needles and forceps are necessary. A needle with a screw end is quite handy for twisting into the cotton and withdrawing the plug if it becomes necessary to do so.

The atomizer bulb is very useful in filling tubes with preservative after they have been drawn out. The bulb is filled with liquid and appressed to the open end of the tube. If compressed a few times the tube can be easily filled. The contents of tubes can be quickly removed by inverting them and compressing an empty bulb against the open end. Air is forced into the tube which replaces the liquid.

Stuffing has also been used as a means of mounting and preserving specimens, but is no longer used to any extent. Bruner has given a full account of stuffing Orthoptera for museum cases.

Inflation of larvae is another form of mounting that is no longer in general usage. The operation is complicated and the specimens are very easily broken after they are prepared. They can be secured from supply houses almost as cheaply as they can be made unless one is especially equipped for inflating them.

Riker mounts are useful in a number of ways. They are of pasteboard construction fitted with a glass cover and filled with absorbent cotton. The bottom should be covered with naphthalene flakes and the cotton replaced. The specimens should then be put in and the cover placed over them. Binding with binding tape is essential to keeping out museum pests. The General Biological Supply House at Chicago has developed a metal box of similar size called the Turtox Metal Mount. It is more durable and binding tape sticks to it more satisfactorily than to the pebble grain finish on most Riker mounts.

V. METHODS OF LABELING THE INSECT COLLECTION.

The methods used in labeling the insect collection are varied. The labeling depends upon the kind of collection and the personal whims of the workers. Some methods used by certain workers are hardly understandable to other workers. One of the principal methods of labeling collections has been to assign each specimen a serial number and enter data under this number in a notebook. Certain amounts of data are necessary for the classification of some insects to species, and collections so labeled are almost worthless if the reference book is lost. The opposite extreme is found among

other workers, especially in other lands, where all the data known about one specimen are attached to the pin below it. The data are written upon sheets of very thin paper and the sheets folded to a compact square before the pin is inserted. Most workers now agree that certain amounts of data should accompany each specimen and that the data should be in such a position on the pin as to be easily read without removing the specimen from its box. It is conceivable that detailed data cannot be given if this rule is to be followed; so a combination of the above types of labeling is growing in favor. The locality, date, and sex labels with the name of the collector should accompany all specimens. A serial number is placed below the collector label, and complete known data are entered under this number in a card index or notebook. Thus the specimen can be identified positively, even though the record indicated by the serial number is lost. As soon as determination to species has been made it should appear as the lowest label and if determination was made by a specialist or if the specimen has any special significance such as having been used as a type, this should be recorded on the name label or on a separate one above the name label.

Opinion is varied as to the amount of information that should be included on the name label. In most cases perhaps the best procedure is to include only the genus, species, and author of the species. In cases where varieties are recognized these names should also appear.

Specimens for class room purposes may well be designated by serial numbers. These numbers can be recorded in a card index along with the name and any known data concerning the specimen. The numbers are an advantage when giving identification tests.

Specimens preserved in liquid should have the labels inside the containers. They may be placed outside, but they often come off and become illegible from some cause or other. Ordinary inks wash off in preservatives; so India ink must be used. Lead pencil may be used for semi-permanent labeling. The sealed tube method affords an excellent means of placing the labels on the inside in such a position that they are readily visible and at the same time do not obscure the specimens in any way.

Labels may be made by a printer who is equipped with very small type, or they may be secured at supply houses at a nominal cost. If one can print nicely he can print his own labels. How-

ever procured, they should be on a good grade of paper and should be printed with permanent ink. This is especially true of labels intended for use in liquid mounts. Beamer ('16) has published an article in which he describes a photographic method for making labels from a typewritten copy. The original is made up with desired spacings and the reductions in photography made as desired. The individual labels are cut from the resulting print.

Each specimen of insects in a collection should have a complete set of labels. Workers modify this rule to suit themselves by placing complete labels on only one specimen in a group of the same species. The name label is the only one that is usually omitted and this for the most part in cabinet collections. Duplicates may very well be labeled in this manner to save time, but there is much to be gained in having each specimen in a collection bear complete labels. There is a great need for uniformity in labeling collections. Workers who expect to trade material should at least be consistent in labeling the material collected by themselves.

VI. PRESERVATIVES

Alcohol is probably the most generally used preservative. It is used alone in strengths varying from 50 to 95 per cent or in combination with other preservatives. Specimens placed in it should be started in lower grades and "stepped up" to the percentage in which final preservation is to be made. It is not especially good for histological work, after preservation for longer than two or three days.

Formaldehyde is recognized as a better preservative for general use than alcohol, but it has a strong odor and affects the eyes and hands if specimens preserved in it are to be studied later. For museum displays and other mounts not intended for study it has a definite use. It is used in strengths varying from 4 per cent. to 38 per cent. Formalin is the trade name for 38 per cent formaldehyde in water and this name is sometimes used instead of formaldehyde 38 per cent. Tillyard uses 4 per cent formalin as a killing and fixing agent and 38 per cent is often used in injection work.

Glycerine has a softening affect upon materials preserved in it and does not penetrate well enough to preserve internal structures. Thus specimens so preserved often become discolored from deterioration. When mixed with alcohol it makes a good preservative, and prevents dessication of specimens if the alcohol evapor-

ates off. Lee has recommended a preserving fluid made from equal parts of 95 per cent alcohol, glycerine and distilled water. He says that specimens preserved in this way may be used for histological purposes or may be used for gross dissection. The author has used material thus preserved for gross dissection and the results are pleasing.

Tothill has used chloral hydrate as a preservative. He killed his specimens by pouring hot water over them and allowing them to drain over a screen or blotting pad for five minutes after which he placed them in a container and poured three times their volume of chloral hydrate (5% aqueous solution) over them and closed the container. After a week he changed this solution to a fresh one of the same strength and left for permanent preservation. He says that he has secured fine results with histological studies made from specimens preserved in this manner and that after four years the specimens were in good condition.

Many other substances have been used as preservatives but few of them are practical now and will not be mentioned here.

VII. Preservation of Color in Insects.

Tower ('03) in an important contribution to the knowledge of insect coloration says that color patterns in insects are of two types: one as old as the insects themselves is composed of cuticular and hypodermal colors in segmentally arranged spots and stripes corresponding somewhat to the position of vital organs; the other, phylogenetically younger, is composed of scales and hairs superimposed upon and partially obscuring the older type. The second type is of purely ornamental value and is quite diverse in arrangement and coloration, while the first type is of more importance. The colors of this type have been designated as "colors pertinent to the species."

Colors in general are of three classes: chemical, physical and and chemico-physical. The chemical colors are divided into three groups: cuticular, hypodermal and sub-hypodermal. Those of the cuticula are black, brown, dark brown, and straw yellows and are located in the primary cuticula. They are permanent, being soluble only in strong mineral acids. The hypodermal colors are subdivided into two groups depending upon their derivation and location. (1) Those located in the hypodermal cells as granules and caused by lipochromes include the chrome yellows, red, vermillion, scarlet, and blue. They are insoluble in water and

ordinary preservatives, but are soluble in ether or other fat solvents. (2) Those located between the hypodermal cells are derived from pigments. They are not permanent. They fade at death or exposure and are soluble in water and ordinary preservatives. They include the colors green, yellow, and white and are largely derived from chlorophyll and xyanthrophyll. The sub-hypodermal colors are green, yellow, and white and are located in the haemolymph or fat body. They, too, are derived pigments and are soluble in water and ordinary preservatives. They fade at death or upon exposure.

The physical colors include white and the irridescent and metallic colors. White unites with other colors to form a sub-group of opalescent colors. Pigment is usually present. The physical colors are produced by surface modifications which reflect, refract or diffract light. They are closely associated with the colors of the next group.

The chemico-physical colors occur widely and are the most brilliant and varied of those produced in insects. They are divided into four groups: (1) reflection pigmental colors, composed of blacks, browns, yellows, and reds and caused by reflection from a polished lamella over a layer of pigment; (2) refraction pigmental colors which include almost all metallic colors, caused by a polished refractive lamella overlying a layer of pigments; (3) defraction pigmental colors in which colors of the above three groups combine to form certain color effects. This group is confined almost exclusively to insects bearing scales.

From the above outline we find that the colors usually retained in preserved specimens are those whose escape is impossible because of insolubility. Few or none of the green, yellow, or white colors are preserved and many of the chemico-physical ones are lost because the pigments essential to their production are lost in preserving methods now in use. In many cases the hypodermal reds, yellows, and blues are dissolved out through the use of ether. Preservation of insects has been done too much by blind chance methods. Insects were placed in preservatives and the colors either stayed or were lost without anyone knowing particularly why. The above work points the way in the opinion of the author to the retention of the most elusive colors. They may be attacked by a chemical method and rendered insoluble in the ordinary preservatives, or an entirely new preservative must be produced.

VIII. METHODS OF HOUSING AND DISPLAY OF COLLECTIONS

Various groups of insects require different methods of housing and displaying as we can readily see from the various methods used in mounting. The pinned collection is ordinarily placed in boxes of various construction and stored in many ways. Individual collections are usually pinned in Schmidt boxes (see paragraph below) and must be opened for reference while larger collections are often housed in boxes with glass tops and placed in large cabinets or arranged in frames for display.

The Schmidt box is a very serviceable one. The top and bottom are two thin pieces cross-grained to prevent warping. The top fits down tightly over a raised ledge of the lower part, making the entrance of pests quite hard. They are made of seasoned pine, white-wood or linden and are 8½″ x 12″ in size, altho a size 12″ x 15″ is also for sale. The bottom is lined with pressed or patented cork. Sheet cork is much better, but more expensive and a later recommendation is the use of Celotex, a composition fibre board used in building construction. It does not rust pins and does not bulge as is often the case with cork.

The U. S. National Museum uses a drawer 2½″ x 18″ x 18″ which fits into a metal case. The box has an inside partition enclosing a space about ¼″ wide all around which is filled with naphthaline to form a poison chamber. The sides and top frames are made of well-seasoned wood and the bottom is of three-ply cross-grained veneer covered with patent cork and lined with white paper. The cover is of glass, fitting into a frame ¾″ wide with a ¼″ tongue which fits into a groove between the inner and outer boxes. A groove is made upon the sides of the boxes to correspond with sliders in the cabinets.

"Professor Comstock of Cornell University has adopted a case with a top and bottom of glass. Its outside dimensions are 16″ x 19″ x 2″ and the covers are both dovetailed and mitered. The top and bottom are alike except that the former is not quite so deep and is grooved to fit over the tongue of the latter. The bottom is covered by a series of wooden blocks each about ⅓″ thick. Twelve of these unit blocks completely fills the box. There are various sizes adapted to fill varying needs, the idea being to put all of one species on a block, thus avoiding the necessity for repinning in case of reorganization of the case." Felt ('99). A decided improvement in this type of box is the substitution of a good grade of sheet cork or Celotex for the board blocks.

The above described boxes are all rather expensive and there is now advertised a box called the Hood Insect Box. It inside dimensions are 8¾" x 12¾" x 2¾" and the frame and cover is made from three-ply veneer with interlocked corners which enables the cover to fit tightly upon the box. The pinning bottom is composed of sugar cane pulp instead of cork and the box is lined throughout with white glazed paper. The outside is covered with water grained heavy black paper making a very neat box. One of the greatest claims of its advertisers is that it is pest proof.

Other boxes have been used by various workers to satisfy particular needs but these are not generally used and will not be discussed here.

Pasteboard boxes are in general use by amateurs because of their cheapness. Other workers sometimes use them to house duplicates. They are variously sized and constructed and are for the most part quite frail. Pests enter them very readily.

Some workers use a loose-leaf method for mounting insects and there are various modifications of the Essig ('26) model. The insects are mounted in cavities cut in corrugated paper and covered with strips of mica. When complete the whole mount is covered with white paper in which holes have been cut to correspond with the mica strips. The data for each specimen should be placed near it on the white paper. This is not a generally used method and does not appear to the author as a very practical one.

Lepidoptera are often mounted in private collections in book form. Some of these are quite elaborate and allow for expansion as new species are collected. A detailed description of one of these occurs in Entomological News 37:282, 1926.

IX. ENEMIES OF THE INSECT COLLECTION

Collections are often set aside for reference or stored away after complete and careful labeling and arrangement without taking proper precautions to prevent attacks by various enemies. There may be local factors working to destroy collections, but chief among the recognized enemies are: (1) museum beetles; (2) book lice; (3) confused flour beetles and other small Coleoptera; (4) greasing; (5) verdigris; (6) mould; and (7) mice.

Museum beetles, of which six species have been reported on insect collections, are perhaps the most serious enemies of the collection. They may occur in collections housed under the very best of conditions and they work rapidly when once established.

Some workers contend that the eggs are laid by the adult beetles upon the boxes and that the larvae crawl through cracks in the boxes while others think that the eggs must be laid directly upon the specimens. Collections that have been closed for years often become infested, but it is not clearly understood how these minute larvae crawl up the enameled surface of the pins in order to reach their food. The larva is the most dangerous stage in the life cycle of these pests, and under favorable conditions the cycle is continuous. The larva feeds within the body of its dried host until food material gives out, or until pupation and emergence. The excrement is pushed outside the host through the entrance hole and it is by this fine brownish dust on the floor of the boxes that the presence of these pests can be detected. Infected specimens, or preferably whole boxes bearing infested specimens, should be removed to a fumigating room and cared for (see page 323).

Museum beetles belong to the order Coleoptera. Three genera of the family Dermestidae are represented. *Anthrenus museorum* L. is an important species and prior to 1890 was found only in collections recently imported from Europe. *Anthrenus verbasci* L. is a common American species and is not so injurious as *Anthrenus museorum* L. *Trogoderma tarsalis* Melsch and *Trogoderma ornata* Say replace the species of *Anthrenus* in the southwest. *Attagenus pellio* L. has been known to inhabit insect collections in the eastern part of the United States, but its chief damage is to furniture.

Book lice are small soft-bodied insects of the family Atropidae of the order Corrodentia. They may be wingless or may possess vestigial wings. They are usually found in collections that have been stored in warm moist places often accompanying mould which will be discussed in a following paragraph. Three species are recognized by Tillyard ('26) as affecting insect collections: *Atropos pulsatoria* Mull., *Lepinotus inquilinus* Heyd. and *Troctes divinatorius* L. They crawl about over the dead insects and eat spines, hairs and lesser chitinized cuticula which with smaller insects may prove to be quite disastrous. They succumb easily to fumigation and may also be killed by dry heating.

The confused flour beetle and other small Coleoptera are rarely serious enemies of the insect collection as dried insects are somewhat removed from their list of food materials. *Ptinus fur* L. is

reported by Riley ('92) as a pest of entomological specimens, but he reports it as being more common in Europe. Blatchley in the "Coleoptera of Indiana" reports this species as being widely distributed by commerce and often injurious to museum specimens. It is more especially fond of furs. *Tribolium confusum* Duval and *Tribolium ferrugineum* Fab. are reported by Riley and Blatchley as doing more or less damage to insect specimens, but these are more closely associated with stored grain products.

Greasing often damages particular groups of insects, chiefly Lepidoptera, Coleoptera, some Hymenoptera and some larger Diptera. It is caused by the melting of fat globules released by deterioration or rupture of the cell walls which retain them. The affected specimens present a characteristic oily appearance and soon become dirty because of the adherence of pieces of lint and particles of dirt from the atmosphere. The colors, scales, and pubescence are likely to become damaged, thus reducing the value of the specimen in the collection. Insects affected with greasing need not be discarded if discovered in time. Muschamp ('12) has devised a means of removing greasing with toluol which he characterizes in his article as "a new solvent." He takes three containers with covers and places toluol in each. Specimens are started in the first where they remain for 24 hours. Most of the grease is loosened in this bath and by two successive baths of 24 hours each he removes all of it. After drying, the specimens are as good as new. A decided advantage for his method is that toluol does not relax the insects and it is not necessary to reset them after these baths.

As a preventive for greasing, St. John ('15) recommends the setting of Lepidoptera over a sponge of cotton wool saturated with formalin. His contention is that the fumes of the formaldehyde enter the bodies and prevent greasing. Gilles ('15) substantiates his views in this process and explains that formaldehyde unites with the chitin and cell walls and prevents their deterioration when in contact with moisture. This, he says, prevents the release of fat globules and thus prevents greasing. His methods differ slightly from those of St. John and he advises that formaldehyde is injurious to the colors of the emeralds, but that other colors remain unchanged. Later workers have shown rather conclusively that only those colors within the chitin will withstand the action of formaldehyde for very long.

Verdigris has been a more serious enemy of the insect collection than it is today. It is caused by the action of certain body juices and acids upon the pins and appears as a bluish corrosion at the dorsal and ventral union of the body and the pin. It has no particular effect upon the insects but the pin may become brittle or eaten away and break. The older white pins were more susceptible to verdigris than the common japanned or enameled ones in use today. The fact that greasing and verdigris are often found on the same specimens has led to the belief that greasing was a cause of verdigris. Greasing is caused by fat globules melting and running over the body while verdigris is the result of the corrosive action of certain body juices and acids upon the pins.

Mould is a serious enemy of the collection in some instances. If stored in a warm moist place mould is likely to occur and collections so infected are very hard to clean so as to be valuable at all. There are probably several fungi causing this condition. A species of Aspergillus has been found in a collection at Urbana, and there are several others common in the air that would thrive under similar circumstances. Ordinary repellents are said to prevent mould as well as insect enemies.

Mice, while not usually recognized as an enemy of the collection, may cause serious damage if specimens are left exposed to dry, or if the boxes are accidentally left open.

X. Fumigation of the Insect Collection

In the control of enemies of insect collections it often becomes necessary to resort to fumigation. Some workers take the stand that fumigation of the collection is one of the necessary parts of its care and that it should be fumigated periodically. In some areas where the evaporation rate of the commonly used repellents is high, this is probably necessary, since the usefulness of the repellent may be spent (before the owner is aware of the fact) and certain enemies may have entered by the time the owner becomes aware that his supply of repellent needs replenishing. Of several well-known and recognized fumigants for this purpose, carbon bisulfide is the most widely recommended. There are various methods that may be used to fumigate collections with carbon bisulfide and where one has a large collection it is advisable to build a tight container or room of known dimensions where several or all the boxes of the collection may be placed for fumigation. The boxes should be opened and placed in such position that the

gas can enter them readily. As soon as everything is arranged, saturate several cloths with the carbon bisulfide and place them in the chamber, preferably near the top as the gas is heavier than air and will press downward. It has been found that if applied at the rate of one pound per 100 cubic feet for 24-36 hours very satisfactory results are obtained from carbon bisulfide.

Some workers prefer to fumigate boxes individually. This is accomplished in two ways and has at least two distinct disadvantages. The first way is to pour into the box a quantity of carbon bisulfide. This method embodies both disadvantages: the liquid stains the floor of the boxes and causes the pins to rust. The second method is to pour the fumigant into a watch glass in a corner of the box. This, if carefully done, removes the staining disadvantage and to some extent the rusting, but the excess moisture occasioned by the addition of the fumigant does not escape readily as the boxes must be tightly closed for 24-36 hours. The individual box method has advantage in the saving of time and the ease with which it may be done, but the preferable way is the one mentioned above. Still others prefer to remove infested specimens to separate boxes for fumigation. This is a good practice if one can be certain that he is removing all the infested specimens. This process may prove to be long drawn out because of the several stages in development of the pest.

Carbon bisulfide has other disadvantages as a fumigant. It is highly inflammable and explosive and must not be used near a flame. Even sparks from switches of electric systems may cause explosions. It is poisonous but its disagreeable odor probably prevents one from becoming seriously injured by its use. This odor is quite disagreeable and forms a third objection to its use as a fumigant. Since the boxes must remain closed, the odor remains for a very long time and is, to some at least, a serious disadvantage especially when the boxes must be opened occasionally or studied. Despite these disadvantages carbon bisulfide is probably the most widely used fumigant for insect collections.

If one is properly equipped for its use hydrocyanic acid gas makes a very good fumigant. This requires very careful treatment as it is a most deadly gas. It was formerly generated by the action of sulfuric acid and water upon sodium cyanide in an earthenware jar, but there has recently appeared a calcium cyanide dust which, when exposed to the atmosphere, liberates hydrocyanic acid gas. There are two kinds of this dust according to Metcalf

and Flint ('28). The 88 per cent dust should be applied at the rate of ¾ pound to each 1,000 cubic feet of space and the amounts for the 48 per cent dust should be about doubled for the same space. This dust should be applied by spreading it about ⅛ inch thick upon newspapers. The fumigation chamber must be kept tightly closed and provision should be made beforehand for opening and ventilating the chamber after the process is complete.

Paradichlorobenzene is also used as a fumigant. It should be resorted to only when danger of fire is great. It has only a fair killing power, and is more expensive than other materials. It may be applied in porous cloth sacks or in tubes covered at each end with fine gauze.

Carbon tetrachloride is also used, and as with paradichlorbenzene, should only be used in cases where the fire hazard is very great. Its killing power is very weak and it is very volatile which makes it a poor fumigant and bars it entirely from use as a repellent.

Older entomologists have used a variety of materials as fumigants largely, perhaps, because of their disagreeable odors. Most of these we now know have only repellent values. Chief among these are found such substances as camphor balsam, oil of turpentine, and forms of creosote.

XI. Safeguarding the Insect Collection

From the discussion in Section IX we may draw some conclusions here as to the methods for safeguarding collections from these various enemies. Perhaps the first thing to be done after one has made certain that all pins are set securely and that specimens loose on pins are securely braced is to see that the boxes are stored in a dry cool place. This will prevent the entrance of mould and book lice and will lessen the amount of greasing to an appreciable degree. It will also remove the probability of warping of boxes as is often experienced in more moist localities. The boxes should be of as tight construction as possible both with regard to fitting of lid and corner construction. Dermestid larvae can make their way through very minute cracks. A tropical method of safeguarding against pests is to stretch a rubber band around the box at the point of union of the box and lid. This prevents the entrance of almost all minute enemies.

Even though all these precautions are taken, a liberal use of some repellent is advisable. Naphthalene cones are available from

supply houses or ordinary moth balls mounted upon pins may be stuck into the boxes as desired. If the head of an ordinary insect pin is heated to red heat in a flame and thrust into a moth ball the naphthalene that is melted by the heat will adhere to the pin upon cooling and the ball may be set anywhere desired. Paradichlorobenzene is often used, but it is too volatile and expensive. Creosote is not so good because of damage of soiling the box or specimens if it should be spilled. Camphor balsam or carbolic acid is an aid in prevention of mould. Mercury pellets are said to pick up particles of dirt as they roll about and are also said to act as repellents.

If one observes all these precautions his collection may escape infestation, but periodic examinations should be made to detect any signs of damage. It is a case where a small amount of work may mean the saving of a valuable collection. These repellents are good and their value has been proven, but too much emphasis cannot be placed upon the fact that they sometimes fail. Their strength may deteriorate just to the extent of allowing a pest to enter, yet the odor may seem strong enough to be effective.

If specimens are received from other collections in exchange these should be subjected to fumigation and a period of probation before being set in the collection.

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THE DISTRIBUTION OF VITAMIN A IN SOME CORN MILLING PRODUCTS

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(Abstract)

Whole yellow corn and each of the nine products representing an almost complete recovery of whole yellow corn by the wet milling process were tested for their Vitamin A content. By the use of these milling products it was demonstrated that most of the Vitamin A is concentrated in the pigmented gluten or high protein constituent of the endosperm. A small amount of Vitamin A was found in the crude corn oil.

Previous work by Steenbock and Coward shows that a much smaller amount of whole yellow corn supplies sufficient Vitamin A to secure a healthy condition in Vitamin A depleted rats when Vitamin D is furnished in the basal ration. These same workers, using the hand-dissected yellow-corn kernel along with a diet supplying Vitamin D, found that Vitamin A is concentrated in the endosperm of the kernel.

In the present investigation, the corn milling products were fed in definite amounts daily to Vitamin A depleted rats. The study included the use of approximately 125 rats of the albino variety. The animals used were bred on a diet low in Vitamin A. When four weeks old, they were placed in individual raised-bottom cages and given a Vitamin A free diet. Vitamin D was furnished by irradiation of the basal food and the Vitamins B and G by 0.5 gm. of brewer's yeast daily. With the depleted animals here used, ophthalmia was developed 25 to 30 days after the beginning of the experimental period. The eye symptoms almost invariably preceded cessation of growth, and were taken as a sign of Vitamin A depletion. When the ophthalmia was persistent, the test food was added to the diet in definite amounts. A quantitative as well as qualitative study of the milling products was made. The Vitamin A value of the test food was judged chiefly by the minimal amount necessary for the ultimate cure of the eyes. A resumption of body growth was also observed.

Whole yellow corn was found to be a rich source of Vitamin A. Eleven per cent in the diet insured permanent cure of ophthalmia and normal growth. Gluten feed was found to be of about the same potency as the whole corn in curative quality. Three of the four milling products that constitute the gluten feed, namely steep water, real slop, and grits, failed in every instance to cure the eyes. Gluten, the fourth constituent, was found, on the other hand, to be extremely high in Vitamin A content, an amount as small as five per cent of the diet curing ophthalmia and producing normal growth. This finding corroborates that of Steenbock and Coward that Vitamin A is concentrated in the endosperm of the yellow maize kernel since the gluten is a part of the endosperm.

Corn germs, the source of the corn oil, were found practically devoid of curing quality, and the germ meal was found totally devoid of Vitamin A. The crude corn oil as pressed from the corn germs was found to be relatively rich in Vitamin A content. Refined corn oil was entirely lacking in curative qualities.

In this study are presented other examples of the interesting but accidental association of Vitamin A with yellow pigmentation, i. e., the concentration of Vitamin A in the yellow-pigmented gluten and in the yellow crude corn oil, both milling products of the yellow maize kernel.

The products here studied, because of the character of the milling process, offer a particularly valuable source of study of the nature of association of Vitamin A with the structural parts of the corn kernel.

SUCCESSIONS IN THE ALPINE REGION OF BRITISH COLUMBIA

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One of the mountains that border the northern side of the Bella Coola valley in the coast mountains in British Columbia is Canoe Crossing Mountain. Dr. Dolmage, in his 1925 geologic report, says that this mountain is somewhat over 6,000 feet above sea level. I have been up this mountain twice and have measured it both times with an aneroid barometer. I found it somewhat less than 6,000 feet. I found that the alpine region begins at 4,500 feet above the floor of the Bella Coola valley.

In this study I have considered the different types of places where pioneer vegetation may start, and I have observed the succession of vegetation that follows each kind of pioneer vegetation.

The vegetation on the snow banks that do not melt away during the summer is of a distinct type. On these snow fields the red snow is very common. The snow is dimpled on the surface, as snow gets when it is exposed to wind and sun. In the dimples the red snow is much thicker than it is on the little ridges between the dimples. The red alga penetrates deeply into the snow. On the northern exposure the red snow is much better developed than it is on the other exposures. This may be due to the effect of the sunlight or to the more rapid melting of the snow on the other exposures. I was unable to follow any succession on the snow.

At the top there is a good deal of live rock that is greatly exposed to the wind and light and cold. Live rock that is more or less vertical and well drained has on it three crustose lichens as pioneers. They are *Rhizocarpon geographicum* and *Acaraspora* sp. and a third that has not been identified. Dr. Plitt has identified the lichens.

The crustose lichens may be overshadowed by one of two lichens. A very small black fruticose lichen, *Alectoria divergens,* grows closely over the crustose lichens. *Gyrophora erosa* is a larger black foliose lichen which sometimes follows the crustose lichens and which sometimes follows *Alectoria.* In the most exposed parts of the live rock there is no further stage in the succession.

In the crevices of the live rock *Silene acaulis* is the one plant that I found.

Near the top of the mountain the live rock may be hollowed out by ice, and in the hollows the snow lies until late in the growing season. Here lichens are not the pioneers, but dark colored moss that has not been identified. The first flowering plant that gets started in the mats of moss is *Saxifraga tolmiei.* Where the moss is not so wet there is a sorediose lichen, *Crocynia* sp., which spreads over the moss. *Saxifraga* is followed by *Carex* sp., and it in turn is followed by a *Juncoides* and another *Carex.*

In most places the next association is one of *Spiraea pectinata,* which is followed by the green-flowered heather, *Phyllodoce glandulosa.* It is followed by the moss heather, *Cassiope mertensiana.* Then comes the climax for the alpine region, namely, the red-flowered heather, *Phyllodoce empetriformis.* In some of the uppermost basined areas the successions went no further than *Cassiope.*

Where the subalpine merges into the alpine on exposed areas of live rock, the heather was followed by a poor growth of low wind timber, *Abies lasiocarpa, Juniperus communis,* and a very little white-barked pine.

By far the most of the side of the mountain is made up of talus. Down the side of the mountain in the talus there may be streams. In other places the water may spread out and make shallow ponds. In still other places the talus may be comparatively dry. It will be wet in the early part of the season but soon becomes drier because all the snow melts away. In still other parts of the alpine the talus may be kept very wet throughout the summer because of very large fields of snow that continue to melt all summer. I studied the successions in these four types of places on the talus.

Along the edge of streams there are two pioneers, namely, *Caltha leptasepala* and *Trollius laxus.* Behind these are *Saxifraga bongardii* and *Cardamine kamtschatica.* On the higher ground there are the *Spiraea* and the three heathers in the same order as mentioned above, with *Phyllodoce empetriformis* as the climax.

Around ponds the mats of moss soon have growing in them *Saxifraga tolmiei,* which is followed by *Spiraea pectinata* on higher ground. This is followed by the heathers. Always *Phyllodoce empetriformis,* the red-flowered heather, is the climax.

Where a thin sheet of water spreads out over the gravel so as to form a kind of quick gravel, two vine-like willows are pioneers. On the edge of the water *Caltha leptisepala* grows, and further out on the higher land is *Spiraea pectinata,* and then the three heathers.

On the comparatively dry talus slope, vegetation starts under conditions of moisture in the early part of the season, but as the season advances the slope becomes better drained because most of the snow has melted and drained away. On such talus slopes the pieces of rocks that make up the talus carry as an inheritance the five lichens that were discussed above. Early on the talus there come two kinds of moss. As the moss dries out it may be covered by a lichen, *Crocynia,* which is sorediose, or by two other larger lichens, *Cetraria islandica* and *Cladonia pyxidata.* Sometimes one of the reindeer lichens is found also. A lichen, *Solorina arctica,* and another large green foliose lichen overwhelm the smaller lichens and the moss. Usually the lichen series is ended with a dense growth of fruticose lichens, among which may be mentioned *Stereocaulon tomentosum* and a reindeer *Cladonia.*

The moss and the lichens are followed by flowering plants, such as *Saxafraga tolmiei* and *Gentiana propinqua.* In other places the following flowers help to make a colorful mat rooted in the moss: *Sibbaldia procumbens, Saxifraga bronchialis, Pentstemon diffsus, Pedicularis scopulorum, Senicio pauciflorus, Oxyria digyna, Saxafraga lyalli,* and many others. A pioneer that grows around large stones that are imbedded in the talus is the mountain form of *Campanula rotundifolia. Silene acaulis* may also be a pioneer where the pieces of talus are close enough together.

Back from the herbaceous association there is found the same succession that I have already discussed, namely, *Spiraea pectinata* and the three heathers. *Phyllodoce empetriformis* is, therefore, the climax on the talus slopes that are well drained.

The last type of talus association that I wish to discuss is developed on very wet talus. In these places the melting snow keeps the slope wet during the entire summer. The water is below the surface of the talus and is moving downward all the while. On such places one finds the best development of the lupine fields of the arctic region. With the lupines and in the wetter places are quantities of *Trollius.* Several colors of Indian paint cup are found, too. Where it is very wet there are creeping willows. Back from such wet meadows where the talus is drier, one always finds

the regular succession of *Spiraea pectinata* and the three heathers. With the heathers there is a *Lycopodium* that is prominent.

We may say that no matter where the pioneers take hold and no matter what the pioneers may be the succession in the alpine is usually terminated by the three heathers of which *Phyllodoce empetriformis* is the climax. Lower down the mountain, where the subalpine merges into the alpine, wind timber becomes the climax, and down in the subalpine the heathers are followed by *Rhododendron albiflorus* and *Veratrum viride*, and this association is followed by the alpine fir, mountain hemlock, and juniper.

PAPERS IN PHYSICS AND CHEMISTRY

EXTRACT FROM THE REPORT OF THE CHAIRMAN

All of the papers that were presented in the Physics and Chemistry Section are herewith transmitted for publication, except the following, which were read by title only, and for which no manuscripts were received.

"Multiplication of Electric Potentials for Measurement," by A. P. Carmen, University of Illinois, Urbana.

"Theories of Calorimetry as Applied to Industrial Processes," by S. W. Parr, representing the Illinois-Iowa Section of the American Chemical Society.

"Biological Decomposition of Fatty Acids," by A. M. Buswell and S. L. Neave, University of Illinois, Urbana.

In the business session held after the reading of the papers, W. F. Schulz, University of Illinois, Urbana, was elected chairman, and J. C. Hessler, Knox College, Galesburg, vice-chairman, for 1930.

ROSALIE M. PARR, *Chairman.*

IMPROVED METHODS IN GRAVITY DETERMINATIONS

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Unquestionably, the most generally used method in the absolute determination of gravity is the pendulum method, in which the length, l, and the period, t, of a pendulum of one form or another, are the quantities to be measured.

To determine t with a degree of exactness which would give the value of "g" to the second decimal place, by counting the oscillations of a pendulum, would require continuous counting for considerably more than twenty-four hours. This, of course, would be a super-human task.

The well known coincidence method comes to our relief by enabling us to determine t over a long interval of time, from a few observations made at the beginning and end of as long a period of time as the pendulum will continue to oscillate. This may be as much as ten or twelve hours, for a well constructed pendulum swinging in a vacuum.

This method has been depended upon by practically all observers who have attempted important gravity measurements in the past. However, the results obtained are in error by an amount which is of serious importance when very exact work is attempted. The required value of t is the period of the pendulum at the end of its run, when it is swinging through an infinitesimal arc, and the coincidence method gives an average value for the entire time the pendulum is swinging. Of course, corrections can be made, but they are so numerous and some of them so uncertain, that there are, or at least ought to be, grave doubts concerning the final result.

In a paper presented at the Rockford meeting, and published in Vol. 15 of the Transactions of the Illinois Academy of Science, the writer described a method of determining the coincidence interval of a pendulum swinging through an infinitesmal arc, but we are now determining the period directly, by a more highly refined and much more satisfactory method.

In figure 1, the light from a 75 watt Mazda lamp, M, is concentrated by the lens, L, upon a narrow slit, S_1, in a metal plate

behind the pendulum. A corresponding slit, S_2, in a thin metal plate attached to the pendulum itself, is carried back and forth in front of S_1 as the pendulum swings. When the pendulum is in the center of its path, a narrow beam of light flashes through the two slits and is picked up by a photoelectric cell, C_1. The current generated by this cell is amplified by a single stage resistance coupled amplifier, A, the details of which are shown in figure 2,

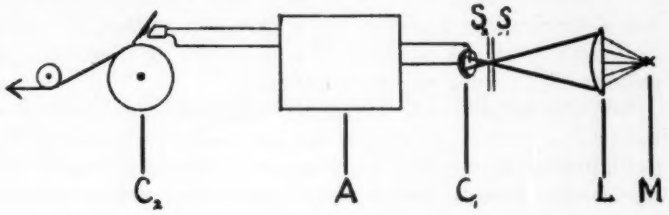

Fig. 1.

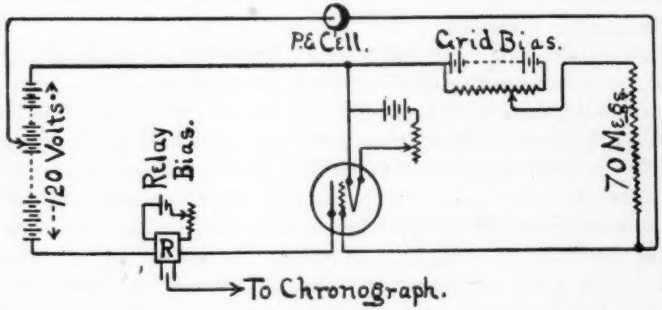

Fig. 2.

and the amplified current records the flash on the ribbon of a paper tape chronograph, C_2, in close proximity to a similar record in seconds, from a standard clock. As the length of a second on the ribbon depends upon the speed at which the chronograph is driven, a given length may be made to represent almost any fraction of a second. With a speed of about 50 cm per second it is quite possible to read the record to within .001 second, so that two

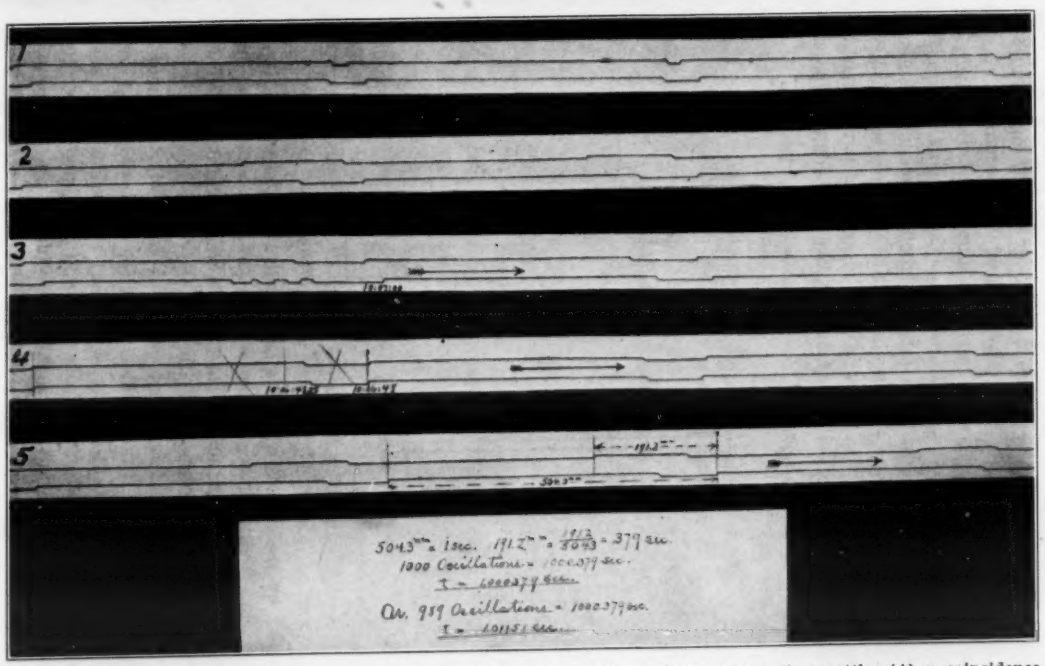

FIG. 3. Chronograph records: (1) large amplitude, (2) small amplitude, (3) a time rattle, (4) a coincidence, (5) a direct measurement of t.

records about 1,000 seconds apart enable us to determine the period of the pendulum to within one or two parts in a million, and the records can be obtained in 15 or 20 minutes instead of running the pendulum from 20,000 to 40,000 seconds. This last mentioned advantage is very great, not simply as a time saver, but because it enables us to determine the period when the amplitude is very small, and during an interval when the *change* of amplitude is imperceptible. With a very sensitive photo-electric cell furnished by the G. M. Laboratories of Chicago and a very sensitive relay, loaned by the Bell Telephone Co., we have found it possible

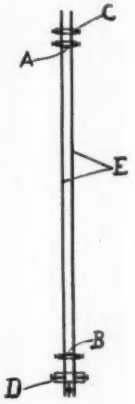

FIG. 4.

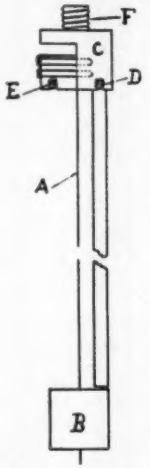

FIG. 5.

to pick up the signals when the amplitude of the pendulum is less than three-tenths of a millimeter. This, for a pendulum a meter long, is about one minute of arc and is well within the range in which *all* the corrections are negligible.

Figure 3 shows actual photographs of some of the chronograph records. Numbers 1 and 2 show the effect of varying amplitude. In No. 2 the amplitude is only .3 mm, but the "break" is as sharp as in No. 1, where the amplitude is 15 mm. No. 3 shows a "time rattle" interjected into the record by means of an independent key, for the purpose of indentifying some particular second. No. 4 shows a coincidence and No. 5 shows the method of determining the period by direct measurements of distances on the chronograph tape.

In determining the length of a pendulum, cathetometer measurements have been almost universally used in the past. Such measurements at best can not be better than about one part in 20,000. If, therefore, we are to determine "g" to within a few parts in a million, we must abandon cathetometer methods entirely.

In our present work we are comparing the length of a pendulum with that of a carefully prepared invar rod, nominally a meter long, the precise length of which is to be certified by the Bureau of Standards, or some other equally competent standardizing bureau.

We are using both simple pendulums and compound reversible pendulums.

Our method with a simple pendulum is as follows: Figure 4 represents a vertical section of a cylindrical pendulum bob, *B*, suspended by means of a bifilar suspension, *A*, from a rigidly supported clamp, *C*. The distance from the lower surface of the clamp to the upper surface of the bob is a trifle more than a meter. Our standard invar rod is provided with a screw at its upper end, and is securely screwed into the clamp at *D*, until the upper end of the rod is in contact with the lower surface of the clamp. The distance from the *lower* end of the rod to the upper surface of the bob is measured by means of a micrometer microscope. The bob is made in cylindrical form in order to facilitate these measurements. Optical tests show that the upper surface of the bob and the lower surface of the clamp are flat to within about half a wave length. The distance from the clamp to the bob is measured from *D* and also from *E*, and if there is any lack of parallelism between the surface of the clamp and the surface of the bob, the mean between the two measurements is taken as the distance at the center. To this is added half the length of the bob, a small negative correction for the effect of the mass of the fine wire suspension upon the center of gravity, and the correction for moment of inertia. The net result is the length, *l*, of the pendulum.

Figure 6 is a photograph of this pendulum mounted in its case, with the front cover removed and with the invar rod and the micrometer microscope in position for measuring the distance from the lower end of the rod to the top of the bob.

Figure 7 is a "close up" view of this last feature.

As the length of the invar measuring rod can be certified to within about a micron, and as the other measurements can easily

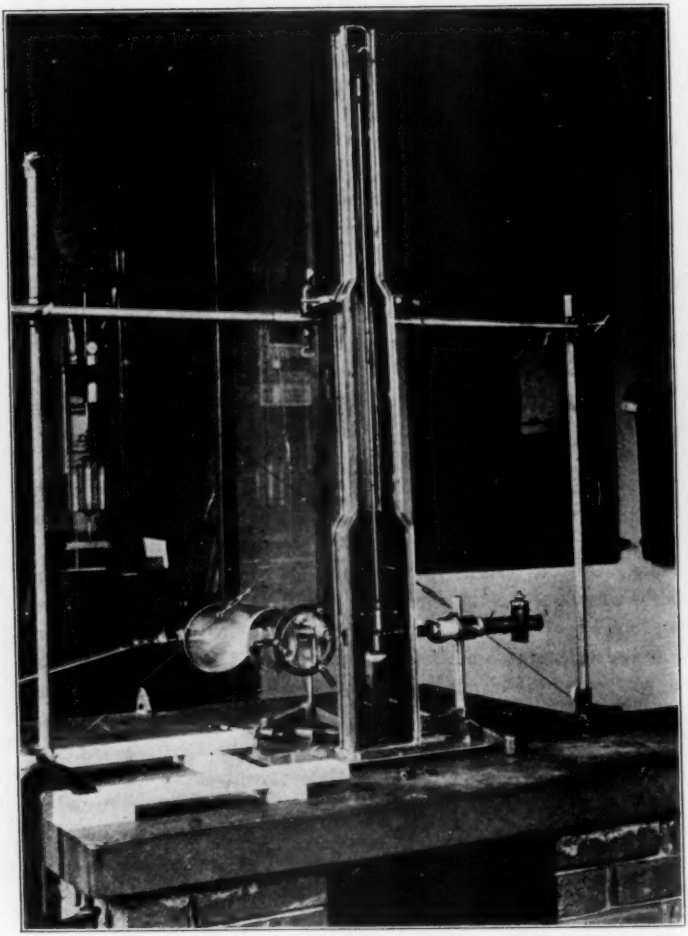

FIG. 6.

be made to within that degree of exactness, there should be no great difficulty in measuring l to within 2 or 3 parts in a million.

Our compound reversible pendulum has been designed with special reference to comparing its length with that of our invar measuring rod. Figure 5 shows the construction of this pendulum. A and B are the upper and lower knife-edge, and C and D are the upper and lower moveable weights. EE are the rods upon which the knife-edge blocks and the weights move. When these weights are so adjusted that the period of the pendulum is the same in the normal position as in the reversed position, then the length, l, is the distance between the knife-edges.

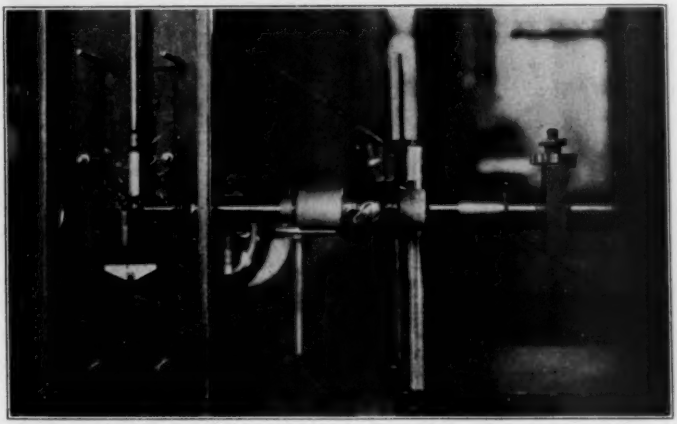

FIG. 7.

This distance is being measured in figure 8, where the pendulum is in a horizontal position and the invar measuring rod is lying between the knife-edges.

The upper end of the pendulum is held firmly in position by means of a screw passing through the upper knife-edge block. A cord is attached to the lower end, carried over a pulley and kept under tension by means of a weight attached to it. This weight is such that the length of the pendulum in a horizontal position is the same as its length in the vertical position, when swinging from its upper knife-edge.

To make the comparison, one end of the invar rod is brought into contact with the upper knife-edge and the micrometer microscope is set with its movable cross hair on the other end of the rod. The rod is then slipped lengthwise until it is in contact with the *lower* knife-edge and the movable cross hair is advanced to the new position of the end of the rod. This measures the amount to be added to the length of the rod to give the length, *l*, of the pendulum.

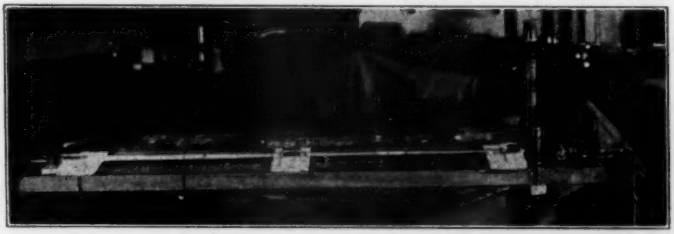

FIG. 8.

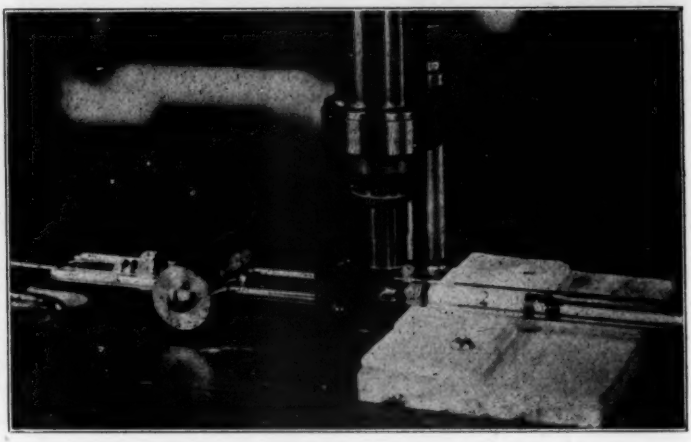

FIG. 9.

Figure 9 is a "close up" view of the end of the invar rod under the microscope.

Figure 10 shows the case in which the pendulum is mounted, and figure 11 is the same case with the front cover removed, showing the pendulum in position, swinging from its upper knife-edge.

As an important modification in the construction of a reversible pendulum, we are substituting roller bearings for knife-edges. The length, l, of a reversible pendulum, is the distance between the knife-edges. A simple enough proposition if the knife-edges are perfectly sharp, but unfortunately this condition can not be fully realized, and if realized, it could not be maintained. If a knife-edge were absolutely sharp, it would not remain so while in use.

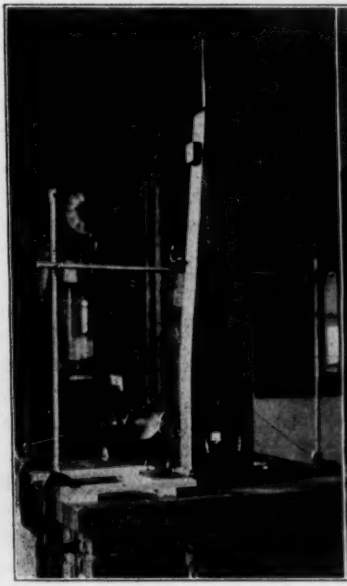

FIG. 10.

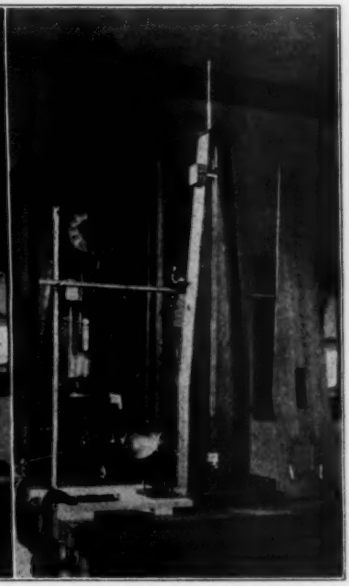

FIG. 11.

If a good knife-edge be examined under a high power microscope it will be found as in figure 12, where we have at *A* represented by the dotted lines what is known as the "missing triangle." If this were all, the pendulum in swinging would simply bob up and down on the edges *e* and *f*. But as a knife-edge wears, it becomes more and more like a roller, and unfortunately its radius of curvature is not known. If the edge would wear into the form of a perfect cylindrical surface as at *C*, it would be more reliable.

If instead of attempting a perfect knife-edge, we substitute cylindrical bearings, or rollers, as at *D*, the length of our pendu-

lum, which is now the distance between the centers of the rollers, is a perfectly definite and constant quantity, and the instrument has the advantage of being simple and easily constructed.

Knife-edges were assumed in the preceding description of our reversible pendulum, but we are actually using well-hardened, highly polished steel rollers, three or four millimeters in diameter. The distance between the surfaces of the rollers is measured with the invar measuring rod and micrometer microscope as described, and to this the diameter of one of the rollers is added. This finally gives the length, *l*, of the pendulum.

In order that the length of our pendulum shall remain constant, the rods *EE* in figure 7 should have an extremely low coefficient of linear expansion. For this reason, practically all modern investigators are using invar, a nickel-steel alloy which ex-

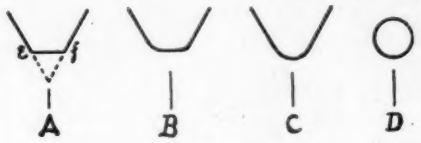

FIG. 12.

pands only about one part in a million, for a change of temperature of one degree. This is quite ideal, but invar is strongly magnetic, and the pull of the earth as a magnet is added to the earth's gravitational pull on the pendulum.

To avoid this disastrous complication we are recommending the use of fused quartz, which has even a lower coefficient of expansion than invar, and is entirely free from magnetic effects. In lieu of fused quartz, well-selected pyrex tubes give very satisfactory results.

It must be understood that the methods described in this paper relate to *absolute* determinations of gravity and not to the vast amount of *relative* work done in recent years with the half-seconds pendulum.

ACKNOWLEDGMENT

The writer of this paper is indebted to Professor Wm. S. Franklin, of the Massachusetts Institute of Technology, for reading the proof and for valuable suggestions.

STUDIES IN COMPARATIVE EFFICIENCIES OF RARE EARTH SEPARATIONS

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Numerous methods available for the separation of the rare earths have frequently been suggested by different investigators who made little or no comparison of the efficiencies of the various procedures. The purpose of this paper is, therefore, to attempt a critical study of the comparative efficiencies of the better-known separations where two or more exist for the same purpose and where the required data are available. It is desired to outline the practical applications of the methods which have actually been used by the authors and to discuss two new physical methods of separation which have recently been suggested.

Methods for the separation of the rare earths may be divided into three classes: 1, fractional crystallization, which depends upon differences in solubility; 2, fractional precipitation and decomposition, which depend upon differences in basicity; and 3, physical methods.

SOLUBILITY METHODS

A very large number of salts of the rare earths have been prepared for the purpose of fractional crystallization, but only a few of these are in common use in rare earth laboratories. Of the simple salts the nitrates and the bromates are the most important. At present complete quantitative solubility measurements are available only in the case of the latter[1]. In these as in other instances the maximum possible efficiency of separation during fractional crystallization is based on the *ratio of solubilities* of the salts being treated. It is sometimes erroneously concluded that the arithmetical difference in solubility is the criterion of efficiency. A little consideration will show that this is not the case. For instance, if two salts, say AX and BX, have solubilities of 25 and 20 parts per 100, respectively, and two other combinations, AY and BY, have solubilities of 50 and 40 parts per 100, respectively, then although the difference in solubilities has been doubled yet the distribution of the two salts in solution in contact with the

[1] James, Fogg, McIntire, Evans and Donovan, J. Am. Chem. Soc. 49, 132 (1927).

crystals will remain in the ratio 5 to 4 in the absence of complicating factors. When the solubility data are available the efficiency of the various salts for the separation of two given rare earths may readily be calculated. In an article of this length it would be impossible to treat all the possible combinations. The figures are given, however, in Table I for the separation of neodymium and samarium which has received intensive study in connection with the concentration of illinium.

The simple rare earth nitrates may be conveniently fractionated from concentrated nitric acid, which represses the solubilities sufficiently to render the ratio large enough to produce a separation. The fractionation is, nevertheless, exceedingly slow, several months of daily treatment being required to obtain even a small proportion of samarium completely free from neodymium. The salts readily

TABLE I—RATIOS OF SOLUBILITIES OF CERTAIN NEODYMIUM AND SAMARIUM SALTS.*

Formula	Ratio	Investigator
$2R(NO_3)_3.3Mg(NO_3)_2.24H_2O$ at 16° C. in HNO_3 $d_4^{16} = 1.325$	$\frac{Sm}{Nd} = 2.49$†	Jantsch, Z. anorg. Chem. 76, 303 (1912).
$2R(NO_3)_3.3Ni(NO_3)_2.24H_2O$	$\frac{Sm}{Nd} = 2.48$	Jantsch, Z. anorg. Chem. 76, 303 (1912).
$2R(NO_3)_3.3Co(NO_3)_2.24H_2O$	$\frac{Sm}{Nd} = 2.25$	Jantsch, Z. anorg. Chem. 76, 303 (1912).
$R(C_3H_5O_3)_3.xH_2O$ (lactate) 20° C.	$\frac{Nd}{Sm} = 2.10$	Jantsch, ibid 153, 9 (1926).
$2R(NO_3)_3.3Zn(NO_3)_2.24H_2O$ at 16° C. in HNO_3 $d_4^{16} = 1.325$	$\frac{Sm}{Nd} = 2.07$	Jantsch, ibid 76, 303 (1912).
$2R(NO_3)_3.3Mn(NO_3)_2.24H_2O$	$\frac{Sm}{Nd} = 1.68$	Jantsch, ibid 76, 303 (1912).
$R[(CH_3)_2PO_4]_3$ 25° C. dimethyl phosphate	$\frac{Nd}{Sm} = 1.59$	Morgan and James, J. Am. Chem. Soc. 36, 10 (1914).
$R(BrO_3)_3.9H_2O$ 20° C.	$\frac{Nd}{Sm} = 1.28$	James and co-workers, ibid 49, 132 (1927).

* Further solubility date on the double nitrates are given by Prandtl and Ducrue, Z. anorg. allgem. Chem. 150, 105 (1926).

† There appears to be a typographical error in the solubility of samarium double magnesium nitrate as given by Jantsch.

form super-saturated solutions and must, therefore, be seeded or else incompletely dissolved. From work at present being carried on in this laboratory it appears that both terbium and holmium nitrates have solubilities intermediate between those of neodymium and samarium in concentrated nitric acid (sp. gr. 1.4). In the experience of the authors the simple nitrates effect a more rapid separation of neodymium and samarium than do the bromates[2].

The rare earth bromates find their principal application in the yttrium group. They have, nevertheless, been used efficiently in the separation of praseodymium and neodymium, and it was through their use that illinium was discovered. Their use for the yttrium earths is rendered less convenient because of slow hydrolytic decomposition. The efficiency of the separation of neodymium and samarium by the bromate method is aided by the intermediate solubility of terbium and in the neighborhood of 0°C. probably by that of gadolinium. Unfortunately, terbium is not sufficiently abundant to be of much use in this connection. The efficiency of the neodymium-samarium separation decreases with increase in temperature, while the samarium-gadolinium separation is slightly more efficient at higher temperatures.

The simple sulfates and a rather large number of organic salts have been fractionated with varying success. The value of any simple salt in the neodymium-samarium separation is, of course, due to the practical reversal of the solubility order. Some qantitative measurements are available for the sulfates, nitrates, oxalates, glycollates, and lactates, but in several of these it is difficult to distinguished between the effects of solubility and basicity.

The rare earth double salts are probably the most important in the resolution of the cerium and yttrium groups and in the separation of the individual members of the cerium group. For the first purpose the alkali double sulfate separation has the distinction of being one of the nearest approaches to a quantitative procedure in all the rare earth separations. The more important double nitrates are those with magnesium, manganese, ammonium, thallium, and nickel, of which the double magnesium nitrate is the best for most purposes. The extremely tedious processes, involving literally tens of thousands of operations which are used in these separations, render extremely desirable the use of salts which will give as little trouble to the worker as possible. In this respect

[2] There is some evidence in the literature that rare earth salts do not always crystallize in the order of their respective solubilities. See, for instance, Jantsch, Z. anorg. Chem. 76, 303 (1912).

the double magnesium nitrates are nearly ideal, as they do not supersaturate readily and may easily be recovered if accidently evaporated to dryness. In addition, their comparatively slight solubility in nitric acid requires the use of a fairly large volume of mother-liquor. This is desirable, as it has been observed that equilibrium and hence maximum efficiency is not reached for several hours and perhaps days after partial crystallization has taken place. It is, therefore, advantageous to have the mother-liquor remain in contact with as large a surface of crystals as possible during the crystallization period, provided that too large a proportion of the salt is not thereby taken into solution.

Other double salts which have been successfully applied are the ammonium double oxalates, used by von Welsbach for the resolution of ytterbium and cassiopeium or lutecium, and the alkali double sulfates already mentioned. In addition to these there are numerous complex salts of which the dimethyl phosphates[3] and the ethyl sulfates are examples. The former especially have great differences in solubility from element to element, but unfortunately their hydrolytic decomposition renders them most unsatisfactory for use.

Basicity Methods

Of almost equal utility with fractional crystallization are the methods of fractional precipitation and decomposition which are founded on the differences in basicity of the rare earth metals. As pointed out by Mellor[4] the efficiency of such methods does not depend directly on the affinity (or basicity) of the earths for the acid but rather on the excess of affinity of the precipitant. In the ammonium hydroxide precipitation "if the affinities of the two earths are represented by 100 and 101 and that of ammonium hydroxide by 150, the affinities on which the precipitation depends would be represented by 150-100=50, and 150-101=49." Obviously, the efficiency is to be increased by decreasing the affinity of the precipitant.

The only quantitative measurements available on the basicity of the rare earths are those of Hildebrand[5] and of Britton[6], on the pH at which precipitation of the hydroxides takes place, and it is questionable whether such information constitutes an accurate

[3] Morgan and James, J. Am. Chem. Soc. *36*, 10 (1914).
[4] Mellor, "A Comprehensive Treatise on Inorganic and Theoretical Chemistry." Vol. 5, p. 540.
[5] Hildebrand, J. Am. Chem. Soc. *35*, 847 (1913).
[6] Britton, J. Chem. Soc. *127*, 2142 (1925).

measure of basic strength. According to Britton, the hydrogen ion concentrations which govern the precipitation of the hydroxides of samarium, yttrium, neodymium, and praseodymium— all about 10^{-7}—are so close together that separation of these elements by fractional precipitation of the hydroxides is impossible. No quantitative information is available on the basicity of the remaining yttrium earths, and it is in the separation of these from yttrium itself that basicity methods are most efficient.

Of the precipitation methods the oldest is by the addition of ammonium hydroxide to a nitrate or chloride solution. This procedure has the disadvantage of permitting local action between the base and the rare earth ions and of the production of a gelatinous precipitate difficult to filter. Various modifications have been suggested by Prandtl[7] and others with a view to eliminating the first of these defects, and such is the purpose of the electrolytic and sodium nitrite precipitations which have been very successful. Magnesium oxide is used on a large scale by at least one commercial firm and organic bases such as aniline have received some application in the separation of the erbium earths. Two of the most satisfactory methods, namely, electrolytic and sodium nitrite basic precitations, have been extensively described in the literature, the former by Dennis[8] and by Kremers[9] and their respective coworkers, and the latter by James[10] and by Hopkins[11] and others. Other suggested precipitants are potassium chromate, oxalic acid, and potassium ferrocyanide, together with a large number of organic acids such as cacodylic, valeric, stearic, nitrobenzoic, acetic, salicylic, and lactic. For details of such separations reference should be made to one of the comprehensive texts on the subject.[12].

In addition to the precipitation methods, fractional decomposition of the nitrates by heating is at once one of the oldest and most satisfactory methods of treating the yttrium earths. Under suitable conditions this method yields a rapid separation of yttrium from erbium or holmium[13].

[7] Prandtl and Lösch, Z. anorg. Chem. *122*, 159 (1922); Prandtl and Rauchenberger, ibid *122*, 311 (1922); *120*, 120 (1921).

[8] Dennis and Lemon, J. Am. Chem. Soc. *37*, 131 (1915). Dennis and van der Meulen, ibid *37*, 1963 (1915). Dennis and Ray, ibid *40*, 174 (1918).

[9] Neckers and Kremers, J. Am. Chem. Soc. *50*, 950 (1928).

[10] Holden and James, J. Am. Chem. Soc. *36*, 1419 (1914).

[11] Hopkins and Balke, J. Am. Chem. Soc. *38*, 2332 (1916).

[12] Little, "A Text-Book of Inorganic Chemistry" (Friend). Vol. 4.

[13] Kremers and Balke, J. Am. Chem. Soc. *40*, 593 (1918); Driggs and Hopkins, ibid *47*, 363 (1925).

PHYSICAL METHODS

Two physical methods, namely distillation and ionic migration, have met with some success in the separation of the rare earths. A third method which attempts to utilize the magnetic properties of these elements has not as yet yielded positive results. Extensive use of distillation and sublimation is discouraged by the very high and relatively slight differences in the boiling points of the stable rare earth compounds. Scandium and thorium have been concentrated by fractional sublimation of the anhydrous chlorides[14], and pure scandium has been obtained by sublimation of the scandium-thorium acetylacetonates[15].

The ionic migration method devised by Kendall and coworkers[16] suggests a relief from the slow process of fractional crystallization. A study has therefore been made in this laboratory of the application of the method to the problem of the concentration of illinium. "In this method an agar gel containing the mixture is placed in a long glass tube behind a gel containing a faster ion of the same sign as those to be separated, and in front of a gel containing a slower ion. On electrolysis the two boundaries of the middle section remain sharp, and if the constituents of the mixture possess appreciably different mobilities, the faster ion gradually concentrates in the front of the section, and the slower in the rear. Recovery of the separated mixture can then be effected by slicing up the gel at the conclusion of the run"[17].

Following the procedure of Kendall and Clarke, three migration tubes were started using a natural mixture of neodymium and samarium chlorides. The 10 cm. rare earth section was preceded by potassium ions and followed by chromic ions. A potential difference of 220 volts produced a current of about 0.3 amperes. After 16 meters of migration the rare earth section was examined spectroscopically, but every portion was found to be identical in composition with the original material.

It was reported by Kendall that "substantially complete separation" of praseodymium and neodymium had been accomplished by this method within ten days. An attempt was made, therefore, to duplicate this separation. After a run of 10 meters during 30 days, absolutely no concentration could be detected.

[14] Meyer and Winter, Z. anorg. Chem. 67, 398 (1910).
[15] Morgan and Moss, J. Chem. Soc. *105*, 196 (1914).
[16] Kendall and Clarke, Proc. Nat. acad. Sci. *11*, 393 (1925); Kendall, Science, LXVII, 163 (1928).
[17] Kendall and West, J. Am. Chem. Soc. *48*, 2619 (1926).

Further runs were made with a natural mixture of samarium and gadolinium and with an artificial mixture of yttrium and erbium. In both of these cases a partial separation was obtained. Measurements of the magnetic susceptibility of the fractions indicated in the first case a concentration of samarium from 53 to 76%, and in the second case a concentration of yttrium from 76 to 89%.

In the opinion of the authors the ionic migration method cannot compete successfully with the established methods of separating the rare earths such as have already been described. One of the most striking disadvantages of the migration method is that it becomes less efficient as the quantity of material is increased while the older methods, especially fractional crystallization, gain in efficiency as the quantity is increased.

The magnetic susceptibility of the rare earths is almost unique in being a property exhibiting very wide variations from element to element. Any fractional method using this property gives promise of being much more efficient than the methods founded on solubility and basicity. A study, therefore, has been made in this laboratory of the conditions under which a magnetic separation might be realized.

In a non-homogeneous magnetic field, that is, one in which the intensity changes from point to point, a magnetic atom will not only be oriented but will be deflected by a force proportional to the magnetic moment of the atom and to the degree of non-homogeneity of the field. Such a field has been obtained by the use of special pole-pieces attached to a large electromagnet. The shape of the pole-pieces and the diminution in intensity of the field are shown in the accompanying figure, which was obtained by sprinkling fine iron filings on photographic paper over the ends of the pole-pieces.

Dilute solutions both aqueous and alcoholic were prepared of the chlorides of samarium and erbium, whose magnetic susceptibilities are in the ratio of about 1 to 40. These were passed very slowly through the magnetic field, and means were provided for the collection of the supposedly more and less magnetic fractions as they emerged. All the results were unsatisfactory inasmuch as no positive separation was obtained. The method appears theoretically sound, but apparently a very much larger magnet must be obtained before a practical separation may be achieved.

Such magnets are available but require tremendous quantities of liquid air for cooling purposes, and their use introduces extraordinary difficulties in the design of the apparatus[18].

[18] A complete description of the experiments on ionic migration and magnetism will be found in a forth-coming publication by the authors in the Transactions of the American Electrochemical Society. (1929).

FRACTIONATION OF THE RARE EARTHS BY ELECTROLYSIS OF AQUEOUS SOLUTIONS

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The various methods used for the separation and isolation of the individual rare earth elements may be divided into three classes: 1, fractional crystallization, which depends on differences in solubility; 2, fractional precipitation, which depends on differences in basicity; and 3, physical processes. The first two methods are undoubtedly the most important.

For the isolation of certain members of the rare earth group, basicity separations, as the second classification is called by the rare earth chemist, are the most efficient. In actual practice the property of basicity is usually interpreted as meaning the relative solubilities of the rare earth hydroxides, the least basic being the least soluble, and *vice versa*. In other words, the least basic rare earths are the first to be precipitated when a basicity method is employed. The order of decreasing basicity of the rare earths generally accepted at the present is as follows: lanthanum, cerium (ous), praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutecium, and scandium. This order, it will be observed, is the reverse of the order of their atomic numbers. Yttrium, which is ordinarily classified with the rare earth elements, has a basicity somewhere between neodymium and dysprosium, somewhere near gadolinium.

Various methods have been used to bring about a partial precipitation of the hydroxides or basic salts. The addition of small amounts of ammonia or caustic alkalies to effect a separation was used early in rare earth chemistry. This method has only been partially successful, perhaps because the precipitated hydroxides are very gelatinous in nature.

The most popular basicity methods are the old basic nitrate fusion method and the fractional precipitation by means of sodium nitrite. In the nitrate fusion method the nitrates are fractionally decomposed by fusion, the basic portion being insoluble in water. The sodium nitrite method was first suggested by Holden and

James[1]. This is carried out by boiling a slightly acid or neutral solution of the rare earth chlorides or nitrates with sodium nitrite. An insoluble basic nitrite of the rare earth is gradually formed.

The hydroxides may also be precipitated when a neutral salt solution of the rare earth chlorides or nitrates is electrolyzed. The hydroxides thus precipitated are formed at the cathode. Here again a fractionation may be effected through differences in the basicities of the earths. Dennis[2] and co-workers electrolyzed solutions of the rare earths, using platinum anodes and mercury cathodes. Kremers and Neckers[3] carried out electrolytic separations on the Ce group earths in this laboratory. They found nitrates and chlorides to be equally satisfactory.

MATERIALS AND METHODS

In the present investigation, the authors were interested in making a rather comprehensive study of the electrolytic method, having in mind the feasibility of the process in regard to the large scale separation of those rare earths which lend themselves to separation by basicity methods.

The anode was made of platinum, a satisfactory substitute not being found. The anode was isolated by means of a porous porcelain cup. In the larger electrolytic cells, a simple open porous cup was used. In the smaller units, a closed cup as shown in Figure 1 was used, thus making it possible to completely immerse the anode compartment in the solution.

The cathode as finally developed was made of molybdenum. All previous investigators used mercury. Various metals were used during the present investigation. Mercury is satisfactory, yet is obviously inconvenient. Platinum is satisfactory, but expensive. Copper, nickel, and iron were partially successful.

When these materials were used reactions sometimes took place which could not be wholly explained. If the electrolyte was a nitrate solution, and the rare earth concentration became too dilute, ammonia was formed at the cathode, thus causing a partial solution of these metals. It was also observed that when the electrolyte contained an appreciable quantity of iron, nickel, or copper, the alternate oxidation and reduction of these metals apparently utilized most of the current input and prevented the for-

[1] Holden and James. J. Am. Chem. Soc. *36*, 2332 (1914).
[2] Dennis. J. Am. Chem. Soc. *37*, 131, 1963 (1915); *40*, 174 (1918).
[3] Kremers and Neckers. J. Am. Chem. Soc. *50*, 950 (1928).

mation of the rare earth hydroxide at the cathode. Molybdenum was found to be quite inert when used as a cathode and was by far the most satisfactory metal tried.

The current densities used were varied. A series of experiments were performed in which the amount of cathode surface exposed was varied to give current densities from 0.01 amperes to 0.5 amperes per square centimeter. Apparently there was no variation in the efficiency of separation due to this.

The electrolyte in this research was made up on nitrate solutions. The best results were obtained with concentrations of approximately 10 per cent of total rare earth oxides. Vigorous mechanical stirring was, of course, always necessary during the electrolysis. The electrolytic cells varied in size from two liter beakers to 80 liter stoneware jars. The units as used are shown in Figures 2, 3, and 4.

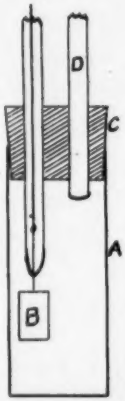

FIG. 1. Diagram of closed cup.
(A) porous cup, 30 mm. diameter.
(B) platinum foil with platinum wire seal through glass and platinum to copper seal.
(C) two-hole rubber stopper.
(D) gas vent.

The current efficiency varied from about 25 to 50 per cent. This low effect may be attributed to a number of factors, such as the reduction of the nitrate to the nitrite or ammonia, the resistance of the solution to the current causing a heating of the solution, the alternate oxidation and reduction of such groups as Fe, Ni, Cu, and Ce, and the diffusion of the nitric acid formed in the anode cup back into the solution.

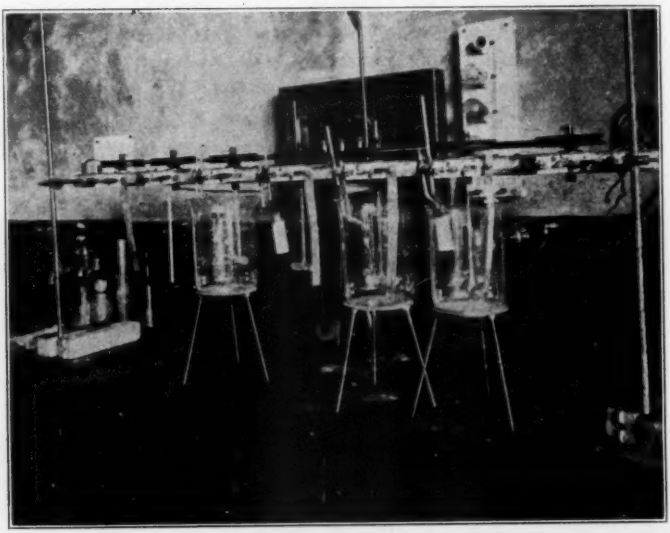

FIG. 2.

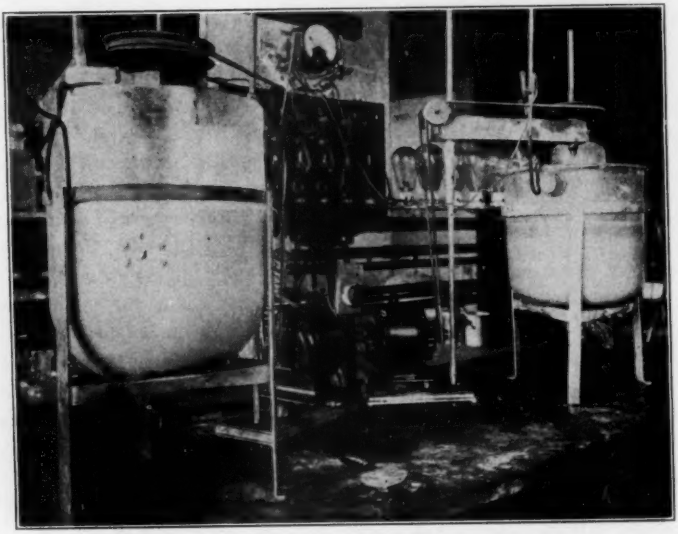

FIG. 3.

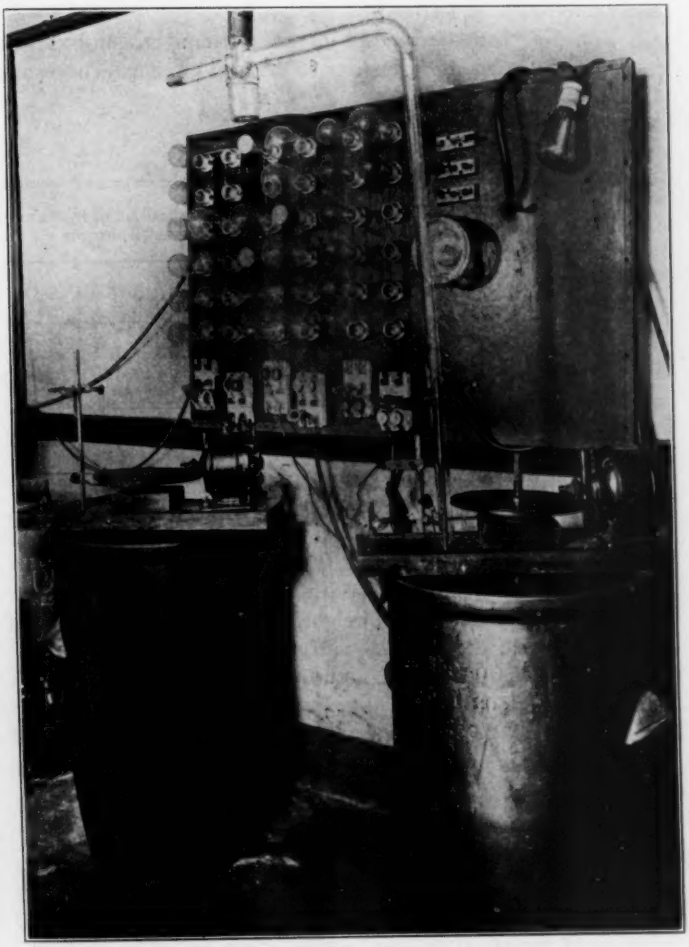

FIG. 4.

TYPICAL RUNS

This method has been used for a period of two years and has thus been given a very thorough trial. It will be necessary to describe only a few typical runs.

Run No. 1 was composed of an yttrium. erbium-holmium mixture containing approximately 93 per cent yttrium. The results are shown in Table I.

TABLE I.

Fraction number	Wt. in gms.	Amps.	Composition of fractions in % of oxide		
			Er_2O_3	Ho_2O_3	Y_2O_3
1	2565	10	8.0	0.5	90+
Residue (Filtrate)	1100		1.0	0.05	98+

Run No. II. The material in this run was composed of 3,510 grams of oxides of the following composition: Er_2O_3, 2.0%; Ho_2O_3, 0.5%; Nd_2O_3, 0.2%; Ce_2O_3 trace; Pr_2O_3 trace; La_2O_3 trace; Y_2O_3, 95% approx. Results are given in Table II.

Run No. III. Some doubt existed in the minds of the authors as to the relative basicities of yttrium and neodymium. Accordingly a mixture, 143 grams in weight, of the following composition was made up: Er_2O_3, 0.2%; Ho_2O_3, trace; Nd_2O_3, 40.0%; Pr_2O_3, 1.0%; Y_2O_3, 58+%. Results of the fractions of this mixture are shown in Table III.

Results seem to indicate very definitely that neodymium and praseodymium are more basic than yttrium.

DISCUSSION OF RESULTS

The order of decreasing basicity of the rare earth elements as given at the beginning of this paper was found to hold in the case of all earths studied. Britton's determinations[4] of the pH of solutions of several of the rare earths at the point at which the hydroxides began to precipitate, partially verify the generally accepted order. Britton's values show yttrium to be less basic than samarium.

TABLE II.

Fraction number	Wt. in gms.	Amps.	Composition ofactions in % of oxide					Remarks
			Er_2O_3	Ho_2O_3	Nd_2O_3	Pr_2O_3	C_2O_2	
1	760	20	4.0	0.5	0.1			
2	325	20	3.0	0.5	0.15			
3	375	20	0.9	0.6	0.15			
4	475	20	0.6	0.45	0.15	trace	trace	
5	560	20	0.5	0.3	0.2	trace	trace	
6	500	20	0.2	0.1	0.4	trace	trace	Highest per cent of yttrium concentrated here.
7	405	20	0.2	0.1	0.5	1.0	0.5	
Residue	110		trace	trace	2.0	1.5	2.0	Practically all of the lanthanum concentrated here.

TABLE III.

Fraction number	Wt. in gms.	Composition of fractions in % of oxide				
		Er_2O_3	Ho_2O_3	Nd_2O_3	Pr_2O_3	Y_2O_3
1	66	0.2	trace	40.0	.....	59+
2	29	.....	.....	60.0	1.0	39
3	25	.....	.....	70.0	1+	28+
Mother liquor	23	.....	.....	80.0	3.0	17

Rapid separations were noted in several cases. The concentration of certain earths was found to be ten-fold in many cases between the fraction and mother liquor. From the standpoint of convenience, the electrolytic method of fractionation is better than other basicity methods. Yttrium can be separated from holmium and erbium very readily by basicity methods. The electrolytic method is very convenient for large quantities of material.

Molybdenum was found to be a very satisfactory cathode material, although copper, platinum, and mercury can be used.

[4] Britton. J. Chem. Soc. 2142 (1925).

ELECTRODELESS RING DISCHARGE

CHAS. T. KNIPP and LEE N. SCHEUERMAN

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Sir J. J. Thomson[1] pointed out many years ago that interesting electrical discharges through a gas may be obtained without the use of metallic electrodes within the discharge tube. The properties of the electrodeless discharge have been the subject of numerous investigations, both abroad and in this country.

The exciting circuit necessary to produce this electrodeless discharge consists simply of two Leyden jars and a stout copper solenoid, surrounding the tube, in series with a large induction coil whose secondary is spanned by a spark gap. When sparks pass across the gap, there are set up in the solenoid high-frequency high-potential currents which induce corresponding currents in the conducting gas within the tube. This induced discharge is in the form of a ring—hence the name. The current flowing may rise to comparatively high values, depending on the nature of the gas and more particularly on its pressure. For most brilliant effects the pressure should be about that of the gas within an ordinary Geissler tube, roughly from 0.05 mm to 0.5 mm of mercury.

Accompanying the discharge and persisting for some moments after it has been cut off, there is to be seen, oftentimes, an interesting after-glow, providing the pressure is just right. This after-glow is not in the form of a ring and is not confined to the length of the exciting solenoid as is the discharge itself, but extends throughout the whole of the tube. It is in general an apple-green illumination (though it may take on different hues), and it may persist in residual air for 5 to 10 seconds after the exciting current in the solenoid has been discontinued.

Thomson[2] also observed that the introduction of a small quantity of fresh gas (the same that was under observation) into the discharge chamber before the after-glow had disappeared (other conditions being favorable) caused the glow to "flash" or brighten up momentarily. The question naturally arose, what are the conditions that obtain within the tube to produce this flash?

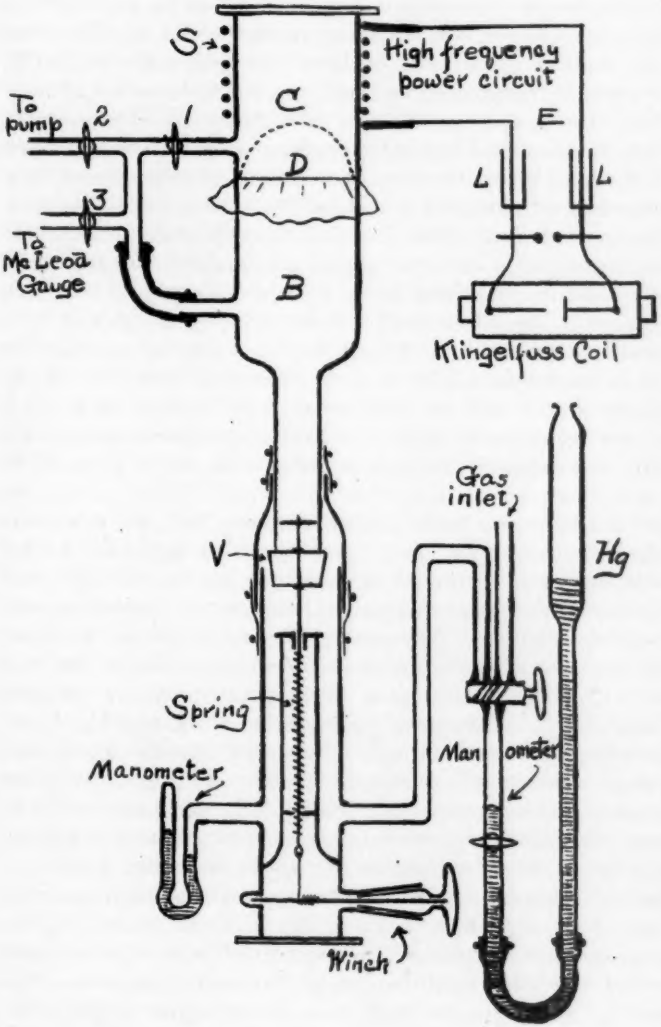
[1] Phil. Mag., series 5, Vol. 32, p. 321, Oct., 1891.
[2] Phil. Mag., series 7, Vol. 4, No. 25, p. 1128, Nov., 1927.

Is it due to the introduction of *fresh* gas, or may the same flash be obtained by merely compressing the gas?

The experimental problem is not as simple as it may seem at first thought. Obviously the compressions should be adjustable as to amounts and they must be quickly made. Some sort of frictionless piston suggested itself. L. W. Florman made a few preliminary observations in this laboratory (1927-28) using two different designs of glass pistons, and succeeded in getting a few "flashes" on *compression*, but owing to mechanical difficulties which prevented him from getting consistent results his observations were not considered conclusive. Another difficulty encountered was that the presence of metal (including mercury) in the discharge chamber seemed to kill the after-glow. The present paper gives an account of an experimental attempt to obtain more conclusive evidence as to the cause of this interesting phenomenon.

The apparatus as ultimately constructed is shown in the accompanying figure. *C* is the discharge chamber about which is placed the solenoid *S* of the high frequency exciting circuit, the details of which are shown. *D* is a rubber disphragm which is held between the two flat ground ends of the divided tube, thus separating the compression chamber *C* from the expansion chamber *B*. Rubber dental dam was used for the disphragm because of its extreme flexibility. At the lower end of the expansion chamber is a large-throated valve *V* for permitting the gas to be introduced quickly into *B* and thus causing a sudden compression of the gas in the chamber *C*. This large-throated valve consists simply of a rubber stopper mounted on a central rod and held firmly against the ground lip of the tube extending down from *B* by a stiff spring as shown. Guides are provided to keep the valve central. To the lower end of the valve stem is attached a winch *W* which permits opening the valve quickly. The small manometer gives an indication of the pressure in the system, while the large manometer is used as a means of measuring and regulating the amount of gas being introduced to bring about the desired compression. The action of this arrangement is apparent from the figure. The system is initially pumped out through the stop-cocks 1 and 2. Stop-cock 3 connects to a McLeod gauge.

The method of operation of the apparatus is to open stop-cocks 1, 2, and 3, then lower the valve *V* by the winch *W* and pump the whole system out to the pressure desired. This pressure is read on the gauge. When the desired pressure is reached stop-


S
High frequency
power circuit
To
pump
2
1
C
E
D
L
L
3
To
McLeod
Gauge
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Gas
inlet
V
Hg
Spring
Manometer
Manometer
Winch

cocks 1 and 2 are closed and then the valve *V*. Thus far the pressures in *C*, *B*, and the lower part of the system are the same, and the diaphragm *D* occupies the unstretched position shown by the solid line. Gas is now introduced in "doses" through the three-way stop-cock by means of the large manometer until the desired pressure, as indicated by the small manometer, is reached. Everything is now ready for the test. The gas in *C* is excited by the high-frequency discharge. After a few moments, when the illumination in *C* has settled down to a constant condition, the exciting current in the solenoid is cut off and the after-glow alone remains. This glow gradually fades, and just before it ceases to be visible the large-throated valve *V* is quickly opened and the excited gas in *C* is suddenly compressed due to the excess of pressure in *B* over that in *C*. The rubber diaphragm now occupies the position indicated by the dotted line. It is at the end of this sequence that the "flash" in *C* occurs. It was soon found that there is a definite compression for each gas used that gives the brightest flash. This ratio is found readily by trial since all factors are under control. With this apparatus the flash on compression can be produced at will.

Earlier in this paper mention was made that one of the reasons why there were so many failures in obtaining a flash or even an after-glow in the initial attempts was due to the fact that metals and mercury, and apparently some non-conductors seemed to kill the after-glow. Thomson was the first to observe this. With the introduction of the rubber diaphragm it was hoped that this difficulty would be eliminated. This, however, was not the case. The sulfur in the processed rubber, being electronegative, killed the after-glow, and for a while it appeared that the rubber diaphragm would have to be abandoned and a return made to a glass piston, unless some flexible material could be found with which to cover the rubber dam. After trying a number of substances, such as vaseline, different kinds of tap grease, and other low vapor pressure lubricants, it occurred to the writer to try pure latex which contains no sulfur. The rubber dam was dipped into the latex and allowed to dry. The coating formed was smooth and seemed to interfere but little with the flexibility of the dam. This covering proved entirely satisfactory,—the after-glow seemed to be in no way diminished. That this was the case was thoroughly tested by introducing latex-covered rubber diaphragms into an

electrodeless discharge tube specially constructed for testing different substances.

With this annoyance removed, a complete series of experiments was undertaken to determine under what conditions a given gas could be made to give this "flash." The discharge itself was found to occur in residual air over a pressure range of 1mm to .0056 mm of mercury (the limit of the Hyvac pump used), and the after-glow was visible over a more limited range from .3 mm to .05 mm mercury. As was previously mentioned, the after-glow in residual air continued for from 6 to 8 seconds under favorable conditions. The "flash" was noticeable at any time from immediately after the excitation of the gas ceased until just before the after-glow disappeared. In fact, it was obtained over the whole range of pressures for which the after-glow was visible. It was not obtained after the after-glow had disappeared.

It was found that the after-glow in residual air seemed to be of two distinct types. One was a glow of quite long duration (4 to 8 seconds) which was prominent at higher pressures (.3 mm to .06 mm). This was of a yellowish hue which changed to a pale apple-green color as the pressure was reduced and the glow gradually disappeared. Over a very limited range of pressure (about .01 mm) no after-glow was noticeable. As the pressure was reduced from .06 mm to .05 a different type of after-glow appeared. This lasted for only a very short time, one or two seconds, and was of a brilliant bluish color, but soon disappeared on further reduction in pressure. At times it was impossible to get a definite separation of the two after-glows, one gradually merging into the other.

Oxygen was next introduced into the apparatus, and the same investigations were carried out with it as with air. The after-glow was found to be a very brilliant bluish-white for the higher pressures, which gradually changed to a blue for the lower pressures. The pressure range of the after-glow for oxygen was roughly the same as that for residual air. The maximum life of the after-glow was also approximately the same as the maximum life in residual air, namely, 6 to 8 seconds. And as was the case in air, oxygen also showed a "flash" upon compression of the excited gas over approximately the same range of conditions.

Nitrogen was in marked contrast to oxygen and air. The after-glow in nitrogen was a brilliant yellow or orange at the higher pressures, changing to a bluish hue and disappearing completely as the pressure was reduced. This after-glow was apparent

over practically the same range of pressures as the first type of after-glow in air. It had, however, a maximum life of about 125 seconds, which varied with the pressure. This after-glow died out very slowly, in sharp contrast to oxygen, which diminished gradually for a few seconds then winked out completely. The "flash" in nitrogen could be obtained at any time while the after-glow was visible. The brilliancy of the "flash" was in direct proportion to the brilliancy of the after-glow. At no time in air, oxygen, or nitrogen, the three gases studied, was a "flash" formed if the compression took place *after* the after-glow had completely disappeared.

A curious thing in the case of nitrogen was that, following the "flash," the after-glow was still visible and continued to die out gradually instead of disappearing completely with the flash as in the case of oxygen. Other interesting results were observed that seemed to be wholly lacking in the case of oxygen; these, however, may have been due to the greater intensity of the after-glow and "flash" in nitrogen. This phase should be studied at greater length. Another curious phenomenon observed in the after-glow of nitrogen was that if the gas was excited and allowed to stand without being disturbed until the after-glow entirely disappeared, then the after-glow could not be made to appear again on subjecting it to the high frequency discharge *without* introducing fresh nitrogen and readjusting the pressure. This also bears further study and verification.

The fact that the after-glow was present when a pure latex rubber diaphragm was used and absent when vulcanized or processed rubber was used seems to indicate quite conclusively that the sulfur and other impurities present in the processed rubber were responsible for the killing of the after-glow. Thomson considered that the after-glows were caused by "systems" formed in the excited gas when the discharge is passing. These systems, which last for only a short time, may be different aggregates from those resulting from chemical combinations and decompositions, and hence may be more easily ionized than the normal gas molecule. Since certain metals placed in the discharge chamber stop the after-glow, it appears that these metals must destroy the "system" formed in the excited gas.

In general, the results of this investigation show that the more electropositive the metal, the smaller is the effect of that metal upon the after-glow. The exception seems to be aluminum. It stands at the head of the electromotive series; yet it had the

greatest effect on the after-glow—killing it almost completely. The aluminum that we worked with, however, lost this anomolous property after a few excitations, and the after-glow returned to almost normality. This would indicate that the sample of aluminum accumulated a charge or protective covering which neutralized its destructive effect first exhibited on the after-glow. It would also indicate the correctness of the explanation advanced by Thomson. His suggestion is that the more electronegative a substance is, the greater is its affinity for electrons and, consequently, the faster it removes electrons from the gas, and hence the more difficult it is for the discharge to pass and for the after-glow to be sustained. Thus the more strongly electronegative the substance, the greater would be its effectiveness in killing the discharge and after-glow.

The "flash" of the after-glow occurs, as seen by the eye, in the form of a flat disc which travels upward from the diaphragm when the gas is suddenly compressed. It seems to accompany a pressure pulse. That it is due to change of pressure and not to the introduction of fresh gas is shown by the fact that the "flash" is obtained when compression is produced by the diaphragm without the introduction of fresh gas into the discharge chamber. This, and other experiments not here enumerated, tend to indicate that the after-glow is due to the illumination which accompanies the recombination of an ionized gas. Since the gas in the discharge tube is ionized the *compression of this gas would push the ions closer together, and thereby facilitate recombination, which is made evident by more intense illumination in the form of a "flash."* After a large part of the gas has recombined, no after-glow is visible, and of course, no "flash" would be obtained. If, however, a "flash" could be obtained upon *sudden expansion* of the excited gas, it could not be explained on the basis of recombination in the ionized gas. Although the effect of expansion has not been exhaustively investigated by the writers, preliminary simple tests indicate that expansion of an ionized gas does *not* cause a "flash."

SUMMARY

1. The vapor pressure of the sulfur in vulcanized rubber is great enough to destroy the after-glow in an electrodeless discharge. Pure rubber (latex) does not affect the after-glow.

2. Many metals (including a few non-metals) affect the after-glow. The more electropositive the metal is, the less is its destructive effect on the after-glow.

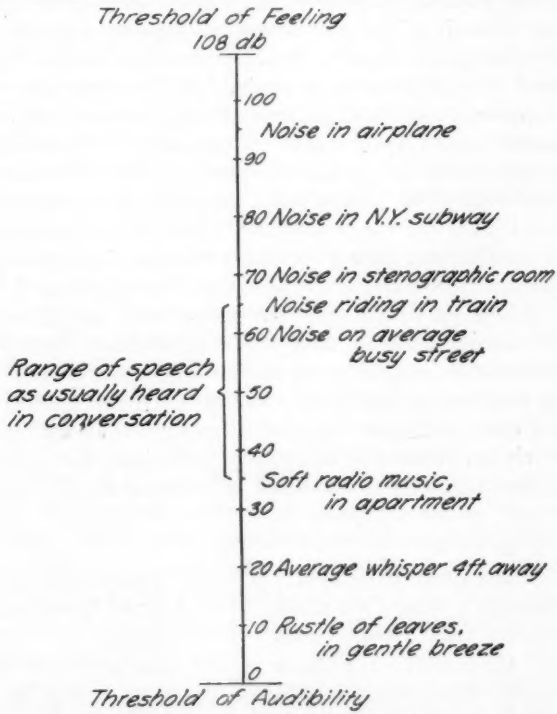
3. The after-glow in air is of two distinct types, one due to a predominance of oxygen and the other to an excess of nitrogen.

4. The "flash" of the after-glow is dependent upon change of pressure, whether the change takes place with or without the introduction of fresh gas into the discharge chamber.

5. The "flash" of the after-glow occurs in a pressure pulse in the excited gas, i. e., in a region of increased pressure. *This suggests that compression facilitates recombination with resulting illumination.*

6. The "flash" of the after-glow does *not* occur when the excited gas is *suddenly expanded* by decrease in pressure. This supports the view expressed above in 5.

7. The compression of the excited gas must take place *before* the after-glow has disappeared. No "flash" can be obtained if the after-glow is not visible at the time of compression.



A Loudness Scale (after Waterfall).

THE LOUDNESS OF SOUND

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The loudness of sound is usually thought of as the intensity, which is an erroneous conception. Recent experiments have established the fact that the loudness of sound is proportional to the logarithm of the intensity. For instance, if one speaker generates an average sound of 10,000 units, 100 speakers would generate 1,000,000 units, so that the intensity would be 100 times greater, but the relative loudness would be in the ratio of log 1,000,000 to log 10,000, or 6 to 4.

Telephone engineers express these values as 10 times the logarithms or "decibels," so that the reduction in the last example would be from 60 to 40 decibels, or db.

The range of loudness as given in the accompanying figure* shows that the threshold sound in zero loudness, rustle of leaves in a breeze is 10 db., conversation loudness varies from 35 to 65, a subway gives 80 db and an airplane 95 db. The loudest sound of 108 db is the threshold of feeling where the loudness of the noise produces pain in the ears. These values are results of actual measurements taken at the Bell Telephone Laboratories, together with measurements in buildings and trains, etc., by Mr. Waterfall.

A further example of the use of loudness is interesting. Suppose two rooms are separated by a partition, and it is desired to know the loudness of the sound transmitted into one room from the other. Assume the loudness of conversation to be 60 db. The absorption of the room, due to suitable padding of the ceiling, will reduce this about 5 db, or to 55 db. The partition between rooms reduces this, say, 40 db, to 15 db, while the padding in the second room reduces it 5 db more to a final loudness of 10 db. Reference to the values in the figure shows this sound is no stronger than the rustle of leaves and therefore not objectionable. However, if the rooms are not padded, and the partition is not efficient, the original 60 db may be reduced only 25 db to 35 db and this sound would be loud enough to be disturbing. The sound insulating values of partitions are now given in decibels (db).

Further examples of the use of loudness could be given, but the foregoing illustrations make clear the modern method of representing sound.

* "A Loudness Scale," by Wallace Waterfall, Engineering News-Record, Vol. 102, p. 60, 1929. (Reproduced here on page 372.)

LOSS OF LIGHT IN A SPECTROPHOTOMETER

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In comparing the intensities of two sources of light, wave length by wave length, with the aid of a spectrophotometer, a number of precautions must be taken.

The usual conditions for sensibility must be observed, namely, two fields to be compared must be placed side by side with only a very fine dividing line between them; these fields must be of sufficient size, subtending an angle of at least two degrees in the field of view; and the fields must be of sufficient intensity but not too bright.

If there is any lack of symmetry in the optical paths of the two beams of light, empirical corrections must be resorted to, in order to allow for this dissymmetry. Stray light must be eliminated by means of suitably placed diaphragms or absorbing material, or at least rendered as symmetrical as possible, as it often forms surprisingly bright images. If for instance we look through a long brass tube with a small aperture at the far end, we see the latter surrounded by a series of bright concentric circles.

The loss of light in lenses and prisms is quite large, and is much increased if the surfaces are not clean. In Nutting's Outlines of Applied Optics it is stated: "Losses by absorption and reflection amount to from 20 to 50 per cent in ordinary corrected objectives. The loss by reflection amounts to roughly 10 per cent for each pair of free surfaces. Losses by absorption are seldom over 5 per cent, but a lens containing glass visibly yellowish in tint may absorb as high as 25 or even 50 per cent in the blue and violet."

If we let I represent the intensity of light incident upon a lens (or prism), and p the fraction of the intensity lost in passing through it, then $I(1-p)$ is the fraction of the intensity which passes through and reaches the next lens. If the same fraction of intensity is lost in each lens (or prism), then $(1-p)$ of the incident intensity $I(1-p)$ will be transmitted by the second lens or $I(1-p)^2$ will be incident on the third lens. It followss that in passing through n pairs of surfaces the incident intensity I will be *cut down to* $I(1-p)^n$.

At the last meeting of the Illinois State Academy of Science, an "optical arrangement" was described *by means of which a Hyde sector disk could be used to better advantage in spectrophotometric measurements. In this arrangement, which is present in only one of the beams compared, and which, therefore, introduces dissymmetry in the system, there are four achromatic lenses and two totally reflecting prisms. The loss of light at the cemented surfaces of the achromats and at the hypothenuse surfaces of the prisms is negligible, but there are six pairs of free surfaces.

A number of tests were made to determine the loss of light in this system. A standard light source was compared with a test source enclosed in a case having an opal glass window for diffusing the light. This opal window was placed at a fixed distance from the collimator slit of the spectrophotometer and the intensity of the test source was determined under these conditions.

The optical arrangement was then inserted in front of the spectrophotometer slit, and the test source with its opal window was placed at the same distance as in the previous test, in front of the collimator slit of the optical arrangement so that the cone of light falling on the two slits was the same in both trials. The width of the slits on all three collimators was made the same. The intensity of the transmitted light was determined under these new conditions.

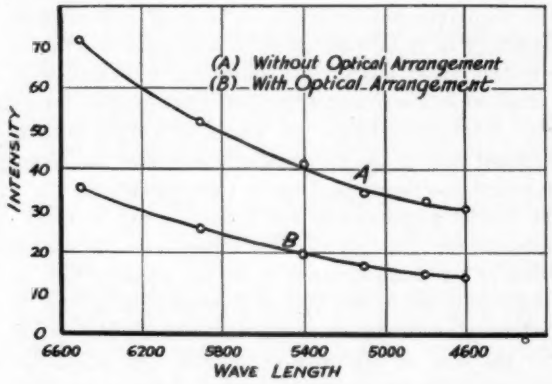
The ratio of these two measured intensities gave the per cent of the incident light which was transmitted and this was determined at a number of wave lengths throughout the visible spectrum.

A sample set of data is shown in the accompanying table and curves, which give the results from the comparison of a 100 and a 400 watt frosted tungsten bulb. The wave lengths are expressed in Angstrom units. The readings are proportional to the intensities of the lights compared, and those marked *B* were taken with the optical arrangement between the 400 watt bulb and the spectrophotometer, those marked *A* with this optical arrangement removed.

Wave length	6500	5900	5400	5100	4800	4600
A	72	52	42	35	33	31
B	36	26	20	17	15	14
Per cent transmitted	50.0	50.0	48.95	48.57	45.46	45.16

* Trans. Ill. Acad. Sci., Vol. XXI, 1929, p. 233.

The average per cent of transmitted intensity is 48.02 and the number of pairs of free surfaces is 6. Therefore, $(1-p)^n = (1-p)^6 = 0.4802$; and solving for p we get $p = 0.115$; that is, each lens or prisms of our system reduces the intensity of the light incident upon it by about 11.5 per cent. It will, therefore, be necessary to use high intensities of the light sources to be tested with this arrangement.



From the curves it will be seen that there is a gradual, almost continuous decrease from 50 per cent to 45.16 per cent in the intensity transmitted, as we pass from the longer to the shorter wave lengths of the spectrum.

As the loss by reflection may be assumed constant for all wave lengths, this increase in loss must be due to the greater absorption of the glass for shorter wave lengths, which is a little less than 5 per cent in this case.

These curves will serve as suitable correction curves for the instrument.

I take this opportunity of thanking Mr. E. Winter, Jr., for assistance in taking the readings.

TEACHING OF CHEMISTRY FROM THE FACTORY VIEWPOINT

L. F. NICKELL

Monsanto Chemical Works, Monsanto.

The vocational outlook of the student in chemistry and chemical engineering has been greatly broadened in the last two decades. Twenty-five years ago, when I first became interested in chemistry, it was for strictly academic reasons; if chemistry were to be a means of livelihood, the greatest probability was that it must be by teaching, research at some educational or governmental institute, or by means of chemical work incidental to some such related industry as cement, fertilizer, zinc smelting, soap, coke, steel, brewing, sugar, water supply, paint, petroleum, or pharmaceuticals. It is true that in the east the opportunities of a chemical student were not quite so barren, but here in the great Mississippi Valley the graduate had an excellent chance to become the protuberance of the potato instead of the tuber itself. When I think of the men of my acquaintance who finished a chemical course in those days, this statement finds ample justification.

Today the picture has changed. Now the young chemist who is industrially minded finds ample chance to enter a strictly chemical industry where his opportunity is limited only by his own native ability, his personality and his chemical training. In fact, the chemical industry of the country today finds itself in much the same position as the aviation industry where expansion is limited only by the number of trustworthy pilots available.

Formerly, the greatest need of the chemical industry was financial; chemistry was a legerdemain that bankers and fiscal agents did not understand and consequently were prone to distrust. But in recent years American chemists have succeeded in translating the language of chemistry into the language of the balance sheet, and to bankers, as well as to the general public, this is not a foreign tongue. The manufacture of chemicals is a highly technical matter and for this reason a chemical plant, to manufacture at low cost must be more thoroughly manned with technical men than most other manufacturing plants. Because of this fact, improvements and changes in processes—even long established ones—have been very rapid and the resulting obsolescence has been

and is tremendous. This situation has made chemical manufacture highly competitive and has introduced a state of flux through which every industry must pass before stability is reached. The ascending road of chemical manufacturing progress is littered with the wrecks of inefficient organizations and individuals, but the survivors have forged ahead with ever increasing power and stamina.

What is the effect of all this on technical personnel? Simply this: Standards required have been consistently raised until the mediocre finds scant consideration and the chemist or chemical engineer of proven ability is at a premium, and the supply of proper calibre newcomers is far enough short of the demand at present as to prove a handicap to the industry. Technical schools, universities, and manufacturers are alive to this situation and measures are gradually being taken to meet it. However, only a beginning has been made in this direction and much more remains to be accomplished. It is my opinion that few, if any, technical courses offer the same opportunity to the young man of energy and creative ability as do chemistry and chemical engineering today.

The matter of training young men to fit them for a place in the chemical industry is an important one. It is now 13 years since I have had the pleasure of being actively engaged in such an important work, and it would therefore be preposterous, if not indeed ridiculous, on my part to venture more than the opinion of the layman on the subject. It is with such a point of view that I continue.

In our industry, the activity of the chemically trained man finds outlet in various days. These may be catalogued as follows:

Research
Analytical control
Supervision of manufacturing operations
Engineering
Executive
Sales

The requirements of each vary considerably with respect to positive characteristics of the individual and even more so in so far as negative characteristics are concerned. Men of widely divergent personality, ability and training may find marked success in one or the other of these activities, and it is the duty of the manufacturer to fit the man to the place for which he is best suited. But for all, a thorough knowledge of the fundamental laws and

principles of chemistry and physics is an absolute necessity. The teaching of such fundamental laws and principles must be accompanied by a sufficient amount of fact to amplify, explain and fix them indelibly in the student's mind. At best, a technical course can only supply a man the tools with which to work. The graduate is not a finished product; he must always continue to be the student and the investigator; his curiosity must always be alive and his imagination must ever be keen and active; but these avail him little if he can not solve his problem when he meets it and recognizes it, and it is a grievous thing to find how often technical men of real accomplishment lack the ability to apply fundamentals such as gas laws, thermal laws, vapor pressure, mass action, or centrifugal force to the problems confronting them.

The courses which teach these fundamentals to the students are general inorganic chemistry, qualitative and quantitative analysis, general organic chemistry, elementary physical chemistry, elementary physics and mechanics, and elementary mathematics. My experience leads me to believe that too often these courses do not receive the attention that they should on the part of teacher and student. They should have the place of prime importance in any technical curriculum. After the student is well grounded with these fundamentals, it becomes the duty of the teacher to see that he gains resourcefulness in applying them; that he learns to make use of such imagination as he possesses and that he acquire reading habits that will enable him to gain knowledge and information on his own account.

Advanced courses in the numerous branches of chemistry serve to broaden the student and to accomplish this result, but I believe that in addition to the laboratory work that usually accompanies such courses, rather complete written reports on special subjects related to the course should be required. I also think the teacher in chemistry would do well to follow the example of the English teacher in giving outside reading assignments to students and requiring reports on such assignments. Nothing has such a narrowing effect upon the student as to get the idea that all that is required of him is to master the contents of a certain textbook from cover to cover. What is he to do in a factory if the problem confronting him can not be found in such a textbook?

The student who is looking forward to work in a chemical factory does well to acquaint himself in a general way with numerous processes such as are outlined in various industrial chem-

istry texts, but such acquaintance should be gained by outside reading rather than by class room instruction. Class time is too valuable to be used for such a purpose. Rather use it to discuss relative merits of different processes for the same product under a given set of conditions; or have the student work out the design for an installation to manufacture some simple product such as glauber salt or sodium thiosulfate, and criticize and discuss his work. Has he chosen the most economical crude materials, and can he show that he has? Can he show that his different pieces of equipment match up properly in size with each other? Is his design ample for the purpose or is it in need of simplification? Does he use the proper type of filter? Should he employ line shafts or direct drives for stirring equipment? Can he justify his choice? Is his equipment properly arranged for the correct routing of material through the plant? Has he an idea of what his cost sheet will look like? Has he chosen the proper material with which to fabricate the several pieces of equipment? It does not matter so much that he has designed his equipment properly, but it does matter what points have occurred to him and whether he has given them due consideration. It does matter whether he has the ability to think for himself. To illustrate: from his most elementary course in chemistry the student uses chemically pure acids, chiefly hydrochloric, nitric, and sulfuric. Does it ever occur to him to ask himself how they are produced from the commercial product? By distillation, perhaps, but in what kind of equipment? I confess that personally as a student I was very little troubled by such a foolish question. I was later, however.

I put first in importance teaching the student fundamentals. Second, teaching him to think. He will have to do it when he enters the factory. He should have the habit when he leaves school.

A course may equip a student admirably for his work in the plant and still fall short of its duty to him. It should awaken in him the ability to use his leisure time pleasantly and agreeably in some other way than reading chemistry, the Saturday Evening Post, and the daily newspapers. There should be some place, however small, in his curriculum where he can at least get a glimpse of some of the humanities, economics, sociology, law, literature, music, art, or whatnot. Let him not lose his ability to become interested in something besides his profession. It will make him a better chemist, a more useful citizen, and a happier man.

PRELIMINARY REPORT OF RESEARCH IN METHODS OF CHEMISTRY TEACHING

MABLE A. SPENCER, H. W. GARNETT, AND ROSALIE M. PARR

Representing the Illinois Association of Chemistry Teachers.

The question whether laboratory work should precede the recitation in chemistry has long been a "bone of contention" among chemistry teachers whenever and wherever they have assembled. The first time we hear of its being discussed and subsequent study made was in 1876, but we have not time here to discuss the findings made at that time. The most recent work that has been done along this line is that which was reported by Prof. Frank M. Greenlaw of Rogers High School, Newport, R. I., to the Division of Chemical Education of the American Chemical Society at its Swampscott meeting last year. Should anyone here present wish to read Prof. Greenlaw's report, it may be found in the October, 1928, issue of the Journal of Chemical Education.

This work reported by Prof. Greenlaw is admirable in character and thoroughness and shows the results of conscientious and painstaking study. The results reported, however, are based on the results of questionnaires sent to a large number of teachers, rather than on actual field work, and Prof. Greenlaw himself feels that in the final analysis the questionnaire is "still a matter of the opinion of the teacher," and that the solution of the problem lies in the laboratory procedure itself, as evidenced by the following excerpt from the report:

"Which relative order of laboratory work and recitation gives best results? The writer realizes that this is still a matter of opinion, owing to the lack of experimental studies leading to definite conclusions." In commenting upon the results obtained, he goes on to say, "In the direct question at issue thirty-eight teachers reply that laboratory work should come first, nineteen favor placing laboratory work after the recitation, and one suggests that the order should vary according to the topic. In the proportion of two to one the group of teachers circularized believe that best results are secured by having the laboratory study *precede* the classroom recitation."

He concludes with the following suggestions:

"A series of lessons might be planned covering a limited but typical list of topics, descriptive, quantitative, theoretical. Alternative development plans, framed by competent teachers would be provided for each topic according to the laboratory or recitation method. Cooperating teachers would be asked to use one plan with one or more divisions. Achievement would be measured by uniform objective tests given when each topic was completed, and retention measured by similar tests given after an interval of several weeks. If the co-operation of a sufficient number of schools could be secured the results would lead to a definite conclusion."

Prompted by the suggestions in Prof. Greenlaw's final paragraph, the Illinois Association of Chemistry Teachers appointed a Research Committee to study the problem. The Committee does not expect fully to *solve* this problem, but hopes to throw out some light as to the nature of the solution. It is the "definite conclusion" at which this committee is striving to arrive, and with this in mind has endeavored to put into actual field work, with the regular teachers, and under as nearly ordinary school conditions as it is possible to secure, the ideas suggested.

Time does not permit the explaining in detail of plans and methods used by the Committee. Outlines, laboratory direction sheets, etc., were devised and sent to 22 co-operating schools which included a total of 35 classes of more than 850 pupils. Upon completion of the work as outlined, uniform objective tests were given. Since observation, reasoning, and memory were the faculties to be tested, the tests contained questions to test these things. The tests were graded, tabulated according to the total scores, and coefficients of correlations.

Instead of taking the Terman Group Intelligence Tests or some similar tests as a means of correlation, we have taken the scholastic averages (S. A.) of the students during their high school experience in all subjects.

The findings of the Committee up to the present time are best studied by means of two tabulations which we shall present at this time. However, this report is not to be considered as final in any sense of the word. It is just the beginning, and a preliminary report is being made now, chiefly because of the fact that a number of the teachers who have known of this work are extremely anxious to hear of its progress.

Nine of the twenty-two schools have been graded and recorded. For the rest the scholastic averages and teachers' estimates have not been returned to the Committee, so that correlations have not been possible. Most of the recall tests given six weeks after the first tests have not been received back by the Committee; hence they have not been incorporated into this report. The same is true of the teachers' estimate sheets except for the scholastic averages.

RECITATION-FIRST METHOD.

School	No. of Pupils.		Observation.	Reason.	Memory.	Test.	Scholastic Average.	Corr. Rec.
1	14	Total	307	315	467	1,122	1,152	
		Average	21.8	22.5	33.30	80.14	82.28	.820
2	18	Total	165.5	257	448.5	1,040.5	1,581	
		Average	9.1	14	24.9	57.7	87	—.403
3	48	Total	950	817	1,355.5	3,592	4,133	
		Average	19.07	21.56	27.0	74.8	85.3	.412
4	23	Total	446.5	447	671	1,762.5	1,943	
		Average	19.4	19.4	29.2	76.6	84.5	.897
5	44	Total	708.5	527.5	1,319.5	3,391.5	3,587	
		Average	16.1	11.9	30.0	88.9	81.3	.482
6	27	Total	583.5	593	367	2,276	2,390	
		Average	21.6	22.0	32.1	84.3	88.6	.667
7	13	Total	236.5	213.5	294.5	851	1,063	
		Average	18.2	16.4	22.7	65.5	81.8	.703
8	19	Total	360	312	583	1,355.5	1,561	
		Average	18.9	16.4	30.6	71.34	82.1	.823
9	17	Total	315.5	285.5	466.5	1,203	1,348	
		Average	18.5	16.7	27.4	70.7	79.2	.732
Totals	223		4,082	3,767.5	6,472.5	16,594	18,758	
Averages			18.3	16.9	29.0	74.4	84.1	.570

LABORATORY-FIRST METHOD.

School	No. of Pupils.		Observation.	Reason.	Memory.	Test.	Scholastic Average.	Corr. Rec.
1	13	Total	244	293.5	454.5	1,121	1,175	
		Average	18.8	22.6	34.2	86.2	90.0	.841
2	12	Total	166	144.5	268.5	645	1,038	
		Average	13.8	12.0	22.4	53.6	86.5	—.019
3	54	Total	1,030	1,164.5	1,459.5	4,222	4,609	
		Average	19.1	21.6	27.0	86.4	85.3	.552
4	22	Total	457	363.5	698.5	1,722	1,862	
		Average	20.8	16.5	31.8	78.4	84.6	.501
5	47	Total	719	778	1,406.5	3,096.5	3,910	
		Average	15.3	16.3	29.9	65.8	83.1	.814
6	26	Total	514	436	748	1,931.5	2,170	
		Average	19.76	16.76	28.7	74.3	83.4	.559
7	16	Total	308	323	464	1,230	1,344	
		Average	19.2	20.1	29.0	76.8	84.0	.737
8	24	Total	443.5	234	468	1,274	1,986	
		Average	18.47	9.75	19.5	53.08	82.75	.311
9	17	Total	301.5	367.5	504.	1,327.5	1,317	
		Average	17.7	21.6	29.0	78.0	77.4	.709
Totals	231		4,183	4,104.5	6,471.5	16,569.5	1,940	
Averages			18.1	17.7	27.6	71.7	84.0	.556

Both of these, however, will be used in the next phase of the work, since we believe that the teachers' opinions are of exceeding importance in this study. It is interesting to note that in some cases the teacher's opinion was verified by the results in his own school but not in others. It is also noticeable, and not at all to be wondered at, that if a teacher preferred the laboratory-first method and had been accustomed to using it, then those students in the group have made better averages in the tests than did those in the same school who had recitation first. If the teacher was an advocate of the recitation-first method, the students in that group did better than those of the same school in the other group.

The accompanying tabulations for nine schools show the total scores, and respective percentage scores, made in different types of learning, together with the correlation of the average test score with the average scholastic average, for each school. The total average percentage scores made by pupils under the recitation-first method are shown to be higher than those made by pupils under the laboratory-first method.

While this is a preliminary report, yet we wish to call attention to the following facts that have been brought out in the study so far:

1. Of the nine schools observed, four of the teachers preferred the laboratory-first method, four favored the recitation-first plan, and one would have the nature of the material determine the method to be used.

2. While the scolastic averages in the two groups vary in individual schools yet the total S. A. averages show neither group to be markedly better than the other in ability. If anything, the recitation-first group was a little the better (averages of 84.1 as compared with 84.0.

3. Observation and memory have higher score in the recitation-first method; reasoning has a higher score in the laboratory-first method; but the general average for the tests is 2.7 per cent better in the recitation-first method.

4. The average coefficient of correlation for the recitation-first method is 0.570, and for the laboratory-first method it is 0.556.

5. No attempt has been made to rate schools nor to study the efficiency of the teacher.

HYDROXYLAMINE AS THE PARENT SUBSTANCE OF A SYSTEM OF ACIDS, BASES, AND SALTS

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Before the beginning of the twentieth century comparatively little thought was given to any other solvent except water. The property of forming solutions which possessed the ability to conduct the electric current was by tacit understanding restricted to water, and the old Lavoisian idea that acids, bases, and salts, owed their peculiar behavior to the presence of oxygen was regarded as an established fact. This idea has since been modified and extended, so that "not only oxygen, but also sulfur, nitrogen, the halogens, and to a recognizable extent even carbon," may be thought of as acid, base, and salt forming elements.[1]

What has heretofore been regarded as the oxygen series of acids, bases, and salts, may be considered as derived from water. To these the prefix aquo- has been applied. Thus, sodium hydroxide, nitric acid, and sodium nitrate may be considered as aquo-base, aquo-acid, and aquo-salt, respectively.

The nearest protype of water, structurally and chemically, is liquid hydrogen sulfide. A great number of substances are known which bear the relationship of typical thio-acids, thio-bases, and thio-salts to it. As examples of these may be cited tri-thiocarbonic acid, H_2CS_3, potassium sulf-hydroxide, KSH, and potassium trithiocarbonate, K_2CS_3.

Ammonia has been studied extensively with respect to its solvent properties. However, it remained to Franklin[2] and his coworkers to recognize its true character as the parent substance of an ammonia system of acids, bases, and salts. It has been found to be the most water-like substance known, and actually does approach water very closely in all of its properties. Naturally the similarity between the corresponding compounds of the two systems is also very striking. Ammono-bases, such as sodium amide, $NaNH_2$, react readily in liquid ammonia with ammono-acids, such as cyanamide, H_2NCN (an ammono-carbonic acid), to yield ammono-

[1] Franklin, J., Am. Chem. Soc. *46*, 2137 (1924).

[2] Franklin, Am. Chem. J. *20*, 820 (1898); *23*, 277 (1900); 47 285 (1912); also publications in the Journal of the American Chemical Society and the Journal of Physical Chemistry.

salts, as in this particular case, sodium cyanamide, Na_2NCM (sodium ammono-carbonate).

A. W. Browne[3] and his students have shown hydrazine to be an excellent ionizing solvent comparable in scope with water and ammonia. The solubilities of many substances in it have been determined and reactions have been found to take place in it with facility. Compounds are known which bear a very definite relationship to hydrazine, viz., sodium hydrazide, $NaNHNH_2$, dihydrazo-sulfuric acid, $(NHNH_2)_2SO_2$, hydrazine dihydrazo-sulfate, $(N_2H_4)_2(NHNH_2)_2SO_2$. That hydrazine may be considered as the parent substance of a hydrazo-system of compounds is hardly disputable in light of these facts.

Many other substances have been studied with reference to their solvent properties. Among these may be included the halogen and halogenoid hydracids, sulfur dioxide, and hydrogen peroxide. Two others which have received extended consideration of late are carbonyl chloride[4] and glacial acetic acid.[5]

A cursory examination of the properties of hydroxylamine, NH_2OH, shows that it, too, may justly be considered the basis of a system of acids, bases, and salts. The striking similarity which this substance shows with water, its solvent properties, and the structural relationship which many substances bear to it, all point to this extremely interesting analogy. The peculiar position which it occupies intermediate between water and ammonia on the one hand, and between hydrogen peroxide and hydrazine on the other, makes its consideration from this point of view of highest theoretical interest. That this idea is not altogether new is attested to by the following quotation from the literature. "Even with respect to its solubilities may this substance be compared with water, as it is easily soluble in ethyl and methyl alcohol, and only barely so in the other common organic solvents. * * * Numerous inorganic compounds combine with it in the manner of solvent of crystallization * * *. It may, like water, be said to possess both basic and acid properties * * * as exemplified by its ability to form salts * * * and the easy replaceability of one of its hydrogen atoms by a metallic atom."[6]

Liquid anhydrous hydroxylamine has been found to dissolve[7] many substances quite readily, such as KI, KCN, and KBr in large

[3] Browne and others. J. Am. Chem. Soc. *48*, 682 (1926). See also Welsh, ibid, *37*, 497, 816, 825 (1915).
[4] Germann and Timpany, J. Am. Chem. Soc. *47*, 2275 (1925).
[5] Conant, J. B., J. Am. Chem. Soc. *49*, 3097, 3062 (1927).
[6] Kohlschütter and Hofmann, Ann. *307*, 314 (1899).
[7] Lobry de Bruyn, Rec. trav. chim. *11*, 18 (1892).

amounts and $NaNO_3$, $Ba(NO_3)_2$, NaCl, and KCl in lesser quantities. Sodium hydroxide, crystallized barium hydroxide, and ammonia are also very soluble. Peculiarly enough, solutions of barium nitrate and potassium sulfate in hydroxylamine are said to give no precipitate when mixed. Many other substances react chemically with hydroxylamine and it is not at all improbable that the solvent in such cases exerts a solvolytic effect upon the solute comparable to the hydrolytic action of water upon certain dissolved salts.

With many substances hydroxylamine combines to form compounds containing hydroxylamine of crystallization. A large number of such hydroxylamates[8], analogous to hydrates, ammonates, and hydrazinates, has been isolated. Furthermore, a whole series of hydroxylamino-basic mercury salts[9], similar to the ammono-basic and aquo-basic compounds, has been prepared. These facts lead to a clearer conception of what have previously been considered as abnormal salts of hydroxylamine, salts in which the ratio of base to acid is greater than would normally be expected. Thus, compounds of the type $(NH_2OH)_2.HX$ and $(NH_2OH)_3.HX$ (where X=Cl, Br, or I) should be considered as hydroxylamates of the normal salts, just as there are ammonium salts with ammonia of crystalization.

Just as sodium hydroxide is called an aquo-base, sodium amide an ammono-base, sodium hydrazide a hydrazo-base, so sodium hydroxylamate, NaNHOH[7], may be considered as a hydroxylamino-base, derivable by the replacement of one of the hydrogen atoms of hydroxylamine by sodium. This compound is actually prepared by the action of metallic sodium upon hydroxylamine in etheral solution and presents an extremely unstable and explosive substance. Other metallic derivatives of hydroxylamine simulate the sodium compound in reactions and properties.

As in the case of ammonia where the negative NH_2 radical may take the place of a hydroxyl group in uniting with non-metallic elements to form ammono-acids, so the NHOH residue enters into combination with metalloids or acidic groups to form hydroxylamino-acids. Due to the fact that there are three replaceable hydrogen atoms in hydroxylamine, six types of acids are possible. Examples of all of these are known, viz., (1) XNHOH, (2) H_2NOX, (3) X_2NOH, (4) XNHOX, (5) X_2NOX, (6)

[8] Crismer, Bull. soc. chim. (3) 3, 114 (1890); Antonow, J. russ. phys. chem. Ges. 37, 479 (1905); Feldt, Ber. 27, 401 (1894).
[9] Adams, Am. Chem. J. 28, 199 (1902).

X_3NO. Among the inorganic compounds only the analogues of sulfurous, sulfuric, carbonic, nitrous and nitric acid are known. The aryl hydroxylamino-acids of the type RCONHOH and RSO_2NHOH (where R represents an aromatic residue) are characterized by well-defined acidic properties, whereas the alkyl hydroxamic acids react neutral in aqueous solution. In this respect they behave like the alkyl ammono-acids (acid amides) which are also neutral in aqueous solution, but which yield well-defined salts when treated with an ammono-base in the parent solvent, liquid ammonia.

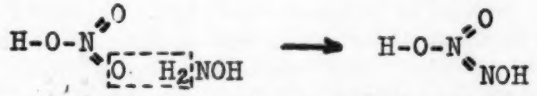
A consideration of several typical acids which are related to hydroxylamine in much the same way as ordinary aquo-acids are to water will serve to bring out the analogy between water and hydroxylamine more clearly.

Of the possible hydroxylamino-sulfuric acids only one, monohydroxylamino-sulfuric acid, $SO_3H.NHOH$, has been obtained in the free state. Several others are known in the form of their salts.

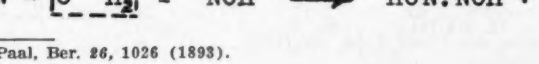
Nitro-hydroxylamic acid, HO(NO)NOH, may be looked upon as nitric acid in which one of the oxygen atoms has been replaced by its hydroxylamine equivalent, the NOH radical.

H–O–H	–OH	=NOH
H_2NOH	–HNOH	=O

Its preparation by the action of ethyl nitrate upon hydroxylamine in alcoholic solution in the presence of alkali lends credence to this conception. The acid is known only in the form of its salts.

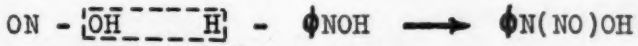


That hyponitrous acid may be regarded as a hydroxylamino-nitrous acid is indicated by the fact that its salts may be prepared by the action of hydroxylamine hydrochloride upon nitrites. The acid itself is formed as the result of the decomposition of hydroxylamine nitrite.[10] Both of these reactions consist essentially in the replacement of an oxygen atom in nitrous acid by the hydroxylamine equivalent, the NOH radical.

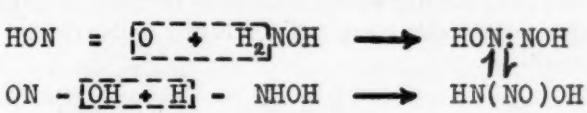


[10] Paal, Ber. *26*, 1026 (1893).

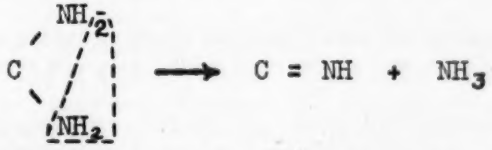
In this connection it is interesting to note that the interaction of phenylhydroxylamine with nitrous acid yields phenylnitroso-hydroxylamine, a substance which is very stable towards alkalies reacting with the latter to form stable salts. The hypothetical parent substance, nitroso-hydroxylamine, may most certainly be regarded as a tautomer of hyponitrous acid, the hydroxyl group in nitrous acid in this case having been replaced by the hydroxylamine equivalent.



In line with the above considerations two possible structures may be assigned to hyponitrous acid, depending upon where the solvolytic action of hydroxylamine has taken place. Both forms undoubtedly exist in equilibrium with each other.

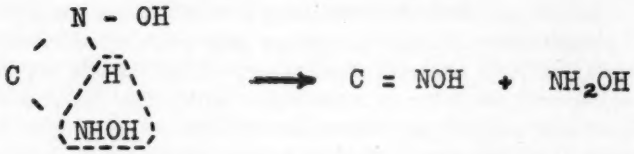


Another interesting deduction which can be made using the conception of hydroxylamine as the parent substance of a system of compounds concerns itself with fulminic acid. In reactions and properties it resembles hydrocyanic acid very closely. Both substances are believed to contain a divalent or unsaturated carbon atom. Franklin[11] has shown that HNC may be regarded as an ammono-carbonous acid derivable by deammonation of the ortho-carbonous acid, as illustrated by the following equation.



The same reasoning may be applied to fulminic acid, a hydroxylamino-carbonous acid.

[11] Franklin, J. Phys. Chem. 27, 167 (1923).



That such a structural formulation of fulminic acid is in accord with its chemical behaviour is indicated by the fact that acid hydrolysis gives hydroxylamine, much as acid hydrolysis of HNC yields ammonia.

Numerous other interesting analogies might be pointed out to show the logicality of the idea of a hydroxylamine system of compounds. The value of any such generalization lies largely in that it may serve to clarify structural relationships which obtain among hydroxylamine compounds and at the same time aid in the classification of hydroxylamine derivatives. As a solvent, particularly as an ionizing solvent in chemical reactions, its great instability will probably always act as a barrier to its extended and widespread use.

SUMMARY

Evidence from the chemical literature has been adduced to show that hydroxylamine may be looked upon as the parent substance of a hydroxylamino-system of acids, bases, and salts.

That such a behavior might be expected is suggested by the peculiar position which it occupies between water and ammonia on the one hand and hydrazine and hydrogen peroxide on the other—to all of which it bears a close resemblance both in physical and chemical properties. All four of these substances have been shown to be ionizing solvents and parent substances of systems of compounds.

Compounds are known which are related to hydroxylamine in much the same way as the usual acids, bases, and salts are to water.

Hydroxylamine dissolves many inorganic compounds and combines with others in the manner of solvent of crystallization.

A TONIC FOR A RUN-DOWN CHEMISTRY SYSTEM

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If you have ever thought your students were becoming disinterested in chemistry or if you have realized that many of them were not doing all the work they were capable of doing, then I have a tonic for them, one that will stir up enthusiasm and develop a wide-awake class.

This scheme revolutionized the chemistry class in the Newton Community High School, changing it from an ordinary class to one that fairly bristled with excitement. The quality and quantity of work done was such that I thought perhaps other teachers might like to know of the plan in case they had a run-down chemistry system.

This project appealed to every type of mind, "the tin cup, the quart, and the gallon," and to those who could draw, those who could write, those who were interested in advertising, etc. The greatest problem facing the classroom teacher is the taking care of individual differences. Unless the assignment appeals to every pupil in the class, it is in that degree a failure. The students oftentimes are not interested, and thus fail the course. It is not because they are lacking in ability but because we do not know them as individuals. We know our subject matter, but not our subjects—the pupils. It has long been an established fact that students differ in mental acumen or I. Q., all the way from dull to near genuises, but they differ even more widely emotionally, tempermentally, and in special abilities, special aptitudes, and peculiar interests. Our assignments, then, must be so elastic that they will take care of these individual differences.

Following is an assignment on Carbon which I think takes care of these individual differences. This assignment was mimeographed and a copy given each student. In this way there was no excuse for anyone not knowing what the lesson was. The assignment is shown here just as it was given to the students. It was designed to appeal to the inferior as well as to the medium and superior student, and it provided ample opportunity for almost everyone to do excellent work if he wished.

CARBON

March 25—April 8, 1929.

60 POINTS

Text book—Brownlee, Fuller, Hancock, Sohon, Whitsit.
Chapter XXIII "Carbon" p. 308-322.
Chapter XXIV "Oxide of Carbon" p. 322-336.
Chapter XXV "Gaseous and Liquid Fuels" p. 336-353.
Chapter XXXVIII "Carbon Compounds" p. 525-560.
Study the above and write answers in ink to the following questions.

A. Due March 28.

1. How does bituminous coal differ from anthracite in appearance and in chemical composition?
2. Why does soft coal make such a smoky fire?
3. Why is anthracite coal preferred for household use?
4. Explain why fence posts are sometimes charred at the end before being placed in the ground.
5. What properties of lampblack make it suitable for printer's ink and for paint?
6. What happens when a solution of brown sugar is filtered through boneblack?
7. What kind of carbon is used in batteries?
8. State briefly how you could distinguish between pulverized charcoal and manganese dioxide.
9. What three conditions are necessary for ordinary burning?
10. Why does water put out a fire?
11. Why is a candle extinguished by blowing?
12. In working with compressed air it is found that combustible materials burn more readily than usual. Explain.

Reference: Brownlee, p. 320-321.

B. Due April 1.

1. Why is hydrochloric acid preferred to sulfuric acid in preparing carbon dioxide from calcium carbonate?
2. Why does soda water effervesce when taken from the tank?
3. Describe three important uses of carbon dioxide, and state the properties on which each use depends.
4. How could you prove that there is carbon in alcohol?
5. By what process may carbon monoxide be obtained from carbon dioxide? Account for the explosions that sometime occur in coal stoves shortly after coal is added. State how these explosions may be avoided.
6. How would you determine whether a gas were hydrogen or carbon monoxide?
7. Why is it that such a large percentage of the cases of asphyxiation from water gas result fatally.
8. How many grams of sulfuric acid reacting with an excess of sodium carbonate are required to produce 200 grams of carbon dioxide?
9. It has been calculated that an average man exhales 464.5 liters (standard conditions) of carbon dioxide in a day. Calculate many grams of starch a plant could make from this.
10. Write the formula for (a) baking soda; (b) cream of tartar. write the equation for the reaction that takes place when these two substances are used in a baking powder. What causes the dough to rise?

Reference: Brownlee, p. 333-335.

C. Due April 5.

1. What is a hydrocarbon?
2. Why is carbon tetrachloride preferable to gasoline for home use in the removal of greese spots from clothing.
3. Define alcoholic fermentation; acetic fermentation.
4. What is an alcohol?
5. Give formula for three common alcohols.
6. What is denatured alcohol? Why is alcohol denatured?
7. What group of elements is characteristic of aldehydes?
8. What relation does formaldehyde bear to wood alcohol?
9. What important chemical changes take place when sweet cider changes to vinegar?
10. How is soap made?
11. What reaction takes place when soap is added to water containing magnesium sulfate? Why?
12. Why do not soap suds form readily when soap is added to salt water?
13. Why is not boiling water used to prepare starch from corn?
14. How is dextrine obtained from starch?
15. Would you expect to find dextrine in the crust or in the center of a loaf of bread?
16. What substance is used to remove coloring matter from crude sugar?
17. Why is vinegar used in making sugar candy that is to be pulled?
18. What is barley sugar? What is caramel?

Reference: Brownlee, p. 559-560-561.

For Reference Material

a. Every Day Chemistry—Alfred Vivian—pages 244-280.
Chapter XXIX "Compounds of Carbon and Hydrogen."
Chapter XXX "Alcohols."
Chapter XXXI "Organic Acids."
Chapter XXXII "Fats, Oils, and Soaps."
b. High School Chemistry—George H. Bruce.
Chapter XXIV "Fuels" p. 299-325.
Chapter XL "Alcohols, Aldehydes, etc." p. 503-515.
Chapter XLI "Other Carbon Compounds" p. 515-524.
c. Modern Baking Powder—Juanita Darrah.
d. Article by Dr. S. R. Powers.
e. Encyclopedia.
f. Pamphlet, "Commercial Glucose and its Uses," George W. Ralphe.
g. Pamphlets about Magic Crystal.
h. "Commercial Glucose as a Food," Victor C. Vaughn, M. D.
i. "The Story of a Grain of Corn," Dr. W. P. Cutter.
j. Public Welfare Service Bulletins.
k. "The Laboratory," Vol. II No. 1.
l. "Current Science," Vol. V. Jan. 14-18, 1929.
m. Journals of Chemical Education.
n. Pamphlet, "The Strength of Sweetness," Woods Hutchinson, M. D. This article may also be found in March number of Ladies Home Journal, 1929.

The above reference material may be found on the reference shelf in the chemistry room.

Pass examination covering material assigned in Brownlee. Must have a grade of 70. Examination will be Monday, April 5, 1929.

25 POINTS

Due April 3.

1. *Make a scrap book.* Newspaper clippings, cartoons, magazine articles, latest developments with carbon, etc. Any phase of carbon or its compounds.

   Not less than 10 pages. Additional points will be given for clever color schemes, good printing, clever arrangement of material.

   10 points for 1st place.
   7 points for 2nd place.
   5 points for 3rd place.

   Note! Scrap books will be entered in a contest put on by "Chemistry Leaflet" State College, Pa. First prize $50, second prize $25, 10 prizes of $2 each.

2. Articles—700 to 1000 words. Due April 2.
   a. "Commercial Glucose and its Uses."
      "A much misunderstood and maligned product. Necessaryary to certain Food Staples, and a good substitute for more expensive ingredients." George W. Ralfe.
   b. Life of Sir Humphrey Davy. Due April 3.
   d. Interdependence of Living Things." Due March 29.
      "The Cause of a Controversy." March 29.
   e. ChapterI. Modern Baking Powder by Juanita Darrah.
      Modern Baking Powder. March 29.
   f. "The Residues from Baking Powder. April 3. Chapter IX.
   g. "The Magic Crystal." Leaflets on reference shelf.
   h. "Commercial Glucose as a Food." Victor C. Vaughan, M. D.
   i "The Story of a Grain of Corn," by Dr. W. P. Cutter.
   j. "All Made from King Corn." Leaflets on reference shelf.
   k. "From Pasture to Pantry." Leaflets on reference shelf.
   l. "The Discover of Gas." Page 3 to middle of page 7. Public Welfare Service Bulletin No. 1; 7th edition, 1927. Due April 4.
3. Make a poster illustrating some phase of Carbon or its compounds.
4. Make a Carbon Tree or a Carbon Wheel with products of Carbon or Compounds hanging on branches of tree or suspended on spokes of wheel. Due April 4.
5. Make a chart showing substances that contain (a) tartaric acid (b) citric acid (c) acetic acid (d) lactic acids (e) tannic acids.
6. "Synthetic Perfumes. Creative Chemistry.

25 POINTS

Laboratory experiments as previously assigned count 25 points.

"CONTRACTS"

10 POINTS

1. 5 slogans which emphasize importance of Carbon or its Com pounds.

   Articles 700 to 1000 words

   a. The Davy Safety Lamp. Ref. "The Laboratory," Vol. II, No. 1.
   b. Practical Uses of Oxalic Acid.
   c. Soap Making.
   d. Candle Making.

e. "Testing Gasoline for Sulphur." Current Science, Vol. V. Jan. 14-18, 1929.
f. "How Grain Alcohol Is Made." List the liquors containing alcohol and the percentage of it in each.
g. The difference between grain alcohol and wood alcohol. List uses of each.
h. The Use of Acetylene Gas for Illuminating Purposes.
i. The Uses of Formaldehyde.
j. Medicinal Uses of Carbon Compounds.
k. Food Preservatives that are Carbon Compounds.
l. Hydrogenation of Oils.
m. Cleansing Powders ($Na\ C_{18}\ H_{35}\ O_2$).
n. The importance of Carbohydrates.
o. The Deadly Carbon-Monoxide.
p. The Valuable Diamond, an Allotropic Form of Carbon.
q. Effervescent beverages depend upon Carbon.
r. The $C\ O_2$ fire extinguisher.
s. Foamite.
t. Petroleum and its Products.
u. Gasoline and Kerosene.
v. How Coal is Made. Public Welfare Service. Page 10.
w. Cellulose—an important Carbon Compound.
x. Tannic Acid and its Uses.
y. "The Strength of Sweetness." Woods Hutchinson, M. D. March number of Ladies Home Journal.
z. How a Pencil is Made.

Laboratory Experiments for Work with Carbon, March 25–April 5.

Experiment 50. Properties of Carbon.
Experiment 51. Preparation and Properties of Carbon Dioxide
Experiment 52. Chemical Fire Extinguisher.
Experiment 54. Baking Powders.
Experiment 78. Fermentation.
Experiment 80. Soap Making (10 additional points will be given for best cake of soap submitted from both classes Note! If toilet soap it will be judged for shape, color scent wrapping. If laundry soap, it will be judged on its merits and must be accompanied by list of reasons why it should excel.)
Experiment 81. Starch.
Experiment 83. Carbohydrates.

Must perform 5 experiments. The ones with a star before them are required to gain the 25 points toward an A.

Extra points will be given for the testing of liquor or hootch (as it is popularly known). The instructor will furnish individual instructions for the test. The liquor will be tested for:

a. percentage of alcohol
b. artificial coloring
c. wood or grain alcohol

Extra points will be given for analyzing vanilla, lemon extract, and patent medicines for alcohol content.

In order to receive a grade of
A you must have 200 points
B you must have 175 points
C you must have 150 points
D you must have 100 points

Note!!! Anyone who does not receive 100 points receives 0. To receive an A one must have the 60 points (for required fundamental work), at least one of the 25 points and must perform laboratory experiments which count 25 points.

"ADVERTISEMENT"

10 POINTS

Write an advertisement for one of the following products:

1. Diamonds
2. Oleomargarine
3. Peanuts
4. Olive oil
5. Soap
6. Cleansing powders
7. Oil of wintergreen
8. Glucose
9. Cane Sugar
10. Charcoal
11. Lighting homes with gas
12. Acetylene gas
13. Gas stoves, fixtures, etc.
14. Honey
15. Library paste
16. Sago
17. Lactose
18. Molasses
19. Vinegar
20. Jellies
21. Mucilage
22. Gum drops
23. Gum arabic
24. Salicylic acid
25. Medicines using carbon compounds
26. Candles
27. Beef tallow
28. Butter
29. Cotton seed oil
30. Oxalic acid
31. Cream of tartar
32. Baking powder
33. Oranges
34. Lemons
35. Gooseberries
36. Currants
37. Vaseline
38. Petroleum
39. Gasoline
40. Kerosene
41. Naphtha
42. Wood alcohol
43. Denatured alcohol
44. Alcoholic beverages
45. Effervescent beverages
46. Cosmetics that contain glycerine
47. Glycerine
48. Hand lotions
49. Ink
50. Malt sugar
51. Starch—laundry
52. Tapioca
53. Guncotton
54. Celluloid
55. Corn starch
56. Dextrine
57. Substances containing cellulose—rainment, etc.
58. Chocolates
59. Face powders
60. Carbona
61. Energine
62. Pyrene fire extinguishers
63. Rubber cement
64. Rayon
65. Grapes
66. Raisins
67. Caramels
68. Paper
69. Corn syrup
70. All kinds of soap
71. Pencils
72. Perfumes
73. Rayon hosiery
74. Motor oil

The regular class discussions and laboratory work was carried out as before. During the course of study a trip was made to the Lincoln Refinery, Robinson, Illinois, so the students could see how gasoline, kerosene, naptha, parrafin, vaseline, etc., were made from oil. The different parts of the project lent outside interest to the regular class work. Points were awarded as the outside material was handed in, and a chart was kept of it. It came in with such rapidity that it was possible to have a complete change for the bulletin board every day for two weeks. The bulletin board proved so attractive that other students flocked to the room and stated a desire for next year to come so they could take part in so interesting a course. Even other teachers marveled at the interest dis-

played by the class. Enough material was turned in to fill at least four or five good sized notebooks.

The students were learning about the properties, uses and compounds of carbon while they were doing something they liked to do. The advertisements, slogans, chart, carbon cycles, posters, scrap books, carbon trees, and carbon wheels, and articles on carbon were exceedingly clever. Here are a few of the slogans:

"Where there's life there's carbon."
"Protect your buildings by using Foamite."
"Out of sweetness came forth strength."
"Carbon is the base of life."
"Use acetylene gas for lighting your farm house."
"Carbon is a great health builder."

There were three carbon trees brought in. The outline of a tree had been drawn on cardboard, and the following articles which contain carbon or organic carbon compounds were hanging on the branches.

Tiny pictures of grapes, Dutch cleanser, lamps, perfumes, corn syrup, diamond rings, hand lotion, peanuts, rayon hosiery, bon-ami, lemons, tapioca, ink, chipso, soap, candles, oranges, energine, carbona, raisins, cocoa, chocolate, cream of tartar, peanut butter, oleomargarine, diamond bracelets, face powder, and cold cream.

Each member of the class was asked to bring either a carbon product or a carbon compound. Then the class wrapped a wheel in rayon and hung the following articles on it: ink, glycerin rose water, napthalene, graphite, glucose, gasoline, candle, carbolic acid, cocoa, oxalic acid, sweet chocolate, Baer's chocolate, shot gun shell, bullets, eraser, peat, gum drop, anthracite coal, bituminous coal, lead pencil, soap, powder, face cream, rayon, coke, charcoal, cotton, paper, piece of inner tubing, synthetic perfume, jello glycerine, cotton seed oil, olive oil, cane sugar, baking powder, motor oil, kerosene, Ethyl gasoline, alco-rub, lamp black vinegar, face powder, citric acid crystals, also the following corn products: Argo Gloss Starch, Cerelose (corn sugar), Globe Pearl Starch, Corn Syrup (3 star unmixed), Argo Corn Starch, Buffalo Corn Gluten Feed, Karo (Red Label), Mazola.

Numerous articles were written. Every student worked out at least one of the 25 point assignments and some did as many as four of them.

The scrap books were unusually clever. A committee of three was chosen from the class to judge the three best scrap books. A blue ribbon was given for first place, red for second, and yellow for third, besides the additional points awarded as was stated in the assignment. The best ones were selected and were entered in a contest sponsored by the "Chemistry Leaflet," State College, Pa. One girl portrayed the life of a "Kewpie." She showed that nearly everything it did had something to do with carbon. All of the facts about the relation of the life of a "Kewpie" to carbon were given in poetry that she composed.

There were 109 advertisements handed in. All of these were accompanied by illustrations. Some of the students made sketches to advertise a carbon product or compound, while others cut out pictures from magazines and used them as illustrations.

Another committee was selected from the class to judge the soap that was made. There was some excellent soap made by the class. They made all different shapes, everything from round to modernistic. There were many different colored soaps, too. Most of them, however, were pink. Nearly every girl brought her favorite perfume bottle to the laboratory and made a sweet smelling toilet soap. Then each designed wrappers for his soap. Some were quite clever. One girl called her "Nuskin." She said her mother told her that she would need "New-skin" if she used it. Another was called "Palmoda." Besides designing the unusual looking wrapper that he did, he also wrote an advertisement for it. His advertisement contained a personal testimony from the most popular girl in high school.

Here is the testimony:

> Miss Dorothy Lee, prominent in society in Newton and Ste. Marie, says, "Palmoda—that soft cleansing power makes me the envy of other girls in my social set. I guard my beautiful complexion with it, for it has always been the one soap which was not harsh to my skin."

One boy made some "Flea Soap," and another made laundry soap. The soap was much better than I had anticipated. Soap was made by all three processes, "cold, semi-boiled and boiled." The students used cocoanut oil, tallow, lard, and cottonseed oil.

At the end of two weeks' study on Carbon the following examination was given. Mimeographed copies were given each student.

April 5, 1929.

Name.....

Put a circle around T if the statement is true; put a circle around F if the statement is false.

1. T F Carbon is one of the most active elements.
2. T F It forms numberless compoundse with hydrogen.
3. T F Every living thing, plant or animal contains carbon in its tissues in the form of organic compounds.
4. T F In the combined form carbon is found as coal, graphite, and diamond.
6. T F Lampblack is a compound of carbon and hydrogen.
7. T F The Safety Lamp was discovered by Edward Goodrich Acheson.
9. T F Anthracite coal produces so much soot when burned that it is not as desirable as bituminous.
10. T F Lead pencils, crucibles, lubricants, are made from boneblack.
11. T F Wood charcoal is used in decolorizing sugar and oils.
12. T F Coke manufactures illuminating gas.
13. T F Choke damp is another name for CH_4.
14. T F Carbon dioxide is a colorless gas with a sharp taste and penetrating odor.
15. T F CO_2 can be liquified by pressure at ordinary temperatures.
16. T F CO is a harmless gas.
17. T F CO burns with a characteristic orange flame.
    b..... c.....
18. T F A small percentage of CO in the air causes headache.
19. T F Water containing dissolved bicarbonates is called water of temporary hardness.
20. T F Permanent hard water can be softened by boiling.

Complete the following statements:

21. $H_2 CO_3 Ca (O H)_2$.
22. Carbon monoxide is formed by:
    1.
    2.
    3.
23. Carbon dioxide is used. a. in charging beverages.
    b..... c.....
24. Name 10 substances that contain some form of carbon.
    1..... 2..... 3.....
    4..... 5..... 6.....
    7..... 8..... 9.....
    10.....
25. The raising of bread depends on the expansion of bubbles of CO by heat. Write the equation for preparation of CO in bread.
26. Name 4 fuels containing carbon. 1.....
    2..... 3..... 4.....
27. Write formula for 1. Ethyl alcohol.....
    2. Wood alcohol.....3. Grain .....
    alcohol ..... 4. Methane.....
    5. Cream of tartar.....
28. Calcium carbonate occurs in the form of 1.....
    2..... ..... 3.....
29. Why is denatured alcohol poisonous?
30. How is formaldehyde prepared?
31. Name 2 uses of formaldehyde. 1.....
    2. .....
32. Vinegar contains .....acid.
33. What is a practical use of oxalic acid?.....
34. The name for cane or beet sugar is.....
    for fruit sugar is.....
    for grape sugar is.....

35. Citric acid is found in 1..... 2..... 3..... 4.....
36. To test for glucose we.....
37. Write formula for preparation of soap.
38. The term soap is applied in general to any..... of a .....
39. "Soft soap" is generally a mixture of the fatty acid.s and..... .....
40. Common "hard soap" is a mixture of fatty acids and.....,
41. The formula for starch is.....
42. Dextrin is prepared by.....
43. .....is the most common aldehyde.
44. Why is vinegar used in making sugar candy that is to be pulled?
45. What is caramel?
46. What is hydrocarbon?
47. Name 3 important substances obtained from corn.
    1..... 2.....
    3.....
48. Name 3 substances obtained by destructive distillation of soft coal.
    1..... 2.....
    3.....
49. Name 5 substances obtained from petroleum.
    1..... 2.....
    3..... 4.....
    5.....
50. List 5 criticisms of the Nitrogen and Carbon projects. Criticisms may be either constructive or destructive. Tell how it could be improved or your reactions to it, etc. I want your honest opinion, it will not affect your score, just tell me exactly what you think of this type of a lesson plan.

During the third quarter I worked out an assignment on "Nitrogen" which was the same general type as this one on Carbon. The requirements for grades, however, were different.

At the end of two weeks the following report was made:

26 out of 29 students made A
2 out of 29 students made B
1 out of 29 students made C

There were no D's and no F's.

In working out this project on Carbon, I changed the requirements for grades. At the end of two weeks the following report was made:

20 out of 29 students made A
5 out of 29 students made B
2 out of 29 students made C
2 out of 29 students made D

There were no F's.

These two reports certainly prove that this type of lesson plan inspires students to work.

The highest record made was 255, this being 55 points more than was required for an A. Out of 29 students 23 passed the examination on Carbon. The highest grade was 93.

There were more A's than most pedagogical books insist one should have, and there were no failures. I could not follow the normal marking curve because of the white heat interest manifested by the students. Each student seemed fired with enthusiasm and worked harder than "A" students had formerly.

Some might think that the students spent more than a fair share of their time on chemistry, but such was not the case. They did not neglect their other work. Out of the 29 students 26 voted that they had learned how to make better use of their time.

This type of assignment has many advantages:

1. It appeals to every type of student.
2. Ample opportunity is offered for anyone to receive a satisfactory grade, if he is willing to work.
3. The independent outside work increases the students reliance on his own efforts.
4. It creates a desire to do research work.
5. The properties and uses of elements are more easily remembered since they are associated with everyday life.
6. The association of elements or chemical compounds with everyday life makes them far more interesting.
7. Stressing the practical value of elements and chemical compounds in our everyday life is a boon to chemistry.
8. When you finish the study of a chemical substance in this manner the student really knows something about chemistry.
9. It appeals to the students because it is like a contest.
10. It teaches students the art of advertising.
11. It teaches students to be critics, as committees are chosen to judge the work handed in.
12. In making scrap books, posters, and advertisements, the students learn the importance of neatness and clever color schemes.

The point I must emphasize is that this kind of a project is merely a tonic. If you wish to improve the tone of your class and pep it up, then give them a dose of this. Beware of an over-dose!

THE OCCURRENCE OF ARSENIC IN GREEN SALAD VEGETABLES

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The investigation had for its purpose the determination of the amounts of As_2O_3 found on head lettuce, cabbage, and spinach, presumably left as residues from arsenical sprays used on the growing plants. Modified Gutzeit method[1] for the determination of arsenic was employed and standard stains were prepared by this method representing from 0.02 to 0.5 mg of As_2O_3. These stains were for the purpose of comparison with stains similarly produced by the unknowns. All reagents employed in all determinations were tested by the qualitative Gutzeit method and only those found to be arsenic free were used.

The vegetables examined included all parts as purchased at the market. They were first shredded then partially dried in six inch evaporating dishes over a hot plate. The material was then transferred to 800 ml Kjeldahl flasks and 10 g of $KHSO_4$ 6 ml of 0.1 molar Cu SO_4 and 50 ml of concentrated H_2SO_4 added.

The vegetable was digested until all carbon was oxidized, then the liquid was diluted with water, cooled and made up to a volume of 0.5 1. An aliquot was transferred to the standard Gutzeit apparatus and the determination made. As a check a 50 g sample of sucrose was likewise digested, diluted and an aliquot run in the same apparatus. The latter showed that the reagents were arsenic free, and that the method was dependable.

Ten heads of lettuce having an average weight of 350.8 g showed the presence of from 0.15 to 0.375 mg of As_2O_3, with an average amount of 0.2675 mg or 0.7 mg per kg of vegetable. Four heads of cabbage having an average weight of 505.9 g contained from 0.25 to 0.375 mg of As_2O_3, an average of 0.325 mg, or 0.6 mg per kg. Four samples of spinch with an average weight of 258 g contained from 0.20 to 0.50 mg of As_2O_3 with an average of 0.319 mg or 1.2 mg per kg.

According to a report from the New Hampshire Agricultural Experiment Station,[2] the dangerous dose of As_2O_3 is 60 mg and the minimum recorded fatal dose is 130 mg. It appears, then, that the amounts of arsenic found in the salad vegetables tested are not sufficiently great to constitute a serious immediate menace.

[1] Scott, Wilfred. Standard Methods of Chemical Analysis, Vol. I (4th edition) pp. 46-52. D. VanNostrand and Co., New York.
[2] N. H. Agr. Exp. Sta. Bul. 163, p. 24, June, 1917.

THE PEDAGOGUE AND INDUSTRIAL CHEMICAL RESEARCH

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Very little has been written on the general subject of how to do chemical research. It is, therefore, no wonder that the modern teacher in our colleges and universities has paid little attention to the subject of teaching methods for chemical research.

The modern scientific pedagogue will explain in infinite detail how such subjects as mathematics, English, and foreign languages should be taught. Every possible reaction of the average student to every possible system of teaching has been noted and recorded. On the other hand, the student taking up research for the first time is turned over to a scientist who, nine chances out of ten, has very little or no interest in pedagogy. One of two things happens: either the student is allowed to flounder helplessly, to sink or swim depending upon his own brains and good fortune, or he is told exactly what to do every day. In the latter case, he becomes a mere automat and no training of any kind is necessary. Loyalty, perseverance, a strong back, and a weak mind are the outstanding desirable characteristics.

Once the student has graduated and gone to work in the research department of a great industry, he will find to his surprise that industrial chemical research is no longer a guessing proposition. He learns that problems are not attacked by hit or miss methods. It has long been supposed that shotgun methods were still prevalent in industry. This is probably not the case. Research labor is too expensive to be used in this old German method. The method itself was extremely simple, for example, to develop a certain process or product a hundred Ph. D. chemists were hired and put on the job to try all of the possible permutations and combinations, hoping that they would find a combination which would be satisfactory in a finite length of time.

It is the purpose of this article to show some of the popular methods of research now in use in our great industrial chemical laboratories.

. Probably the most common type of industrial chemical research is the invention of a new and better process to produce an old and well-known product. The author has analyzed a great many developments of this type, and without exception they have an underlying fundamental method of attack. The strange part of it is that this fundamental method of attack proved to be identical in all the cases examined.

An outline of this method follows:

1. A search of the literature.
2. The selection of a possible process, whether feasible or not, which has the best economic foundation for the particular conditions that have to be met.
3. A list of all of the apparent factors. (By factors are meant pressure, temperature, concentration, and the physical and chemical characteristics of the various substances involved in the reaction.)
4. A list of all the apparent variations of these factors.
5. A selection of the most important factor from the first list, recognizing the basic requirements of this particular reaction.
6. A selection of the best means of varying this factor.
7. The actual experimentation. (If unsuccessful, another selection should be made of the means of varying the factor or if preferred, another factor should be selected to be varied.)

This outline can be best explained by going over one or two examples. Years ago there did not exist a satisfactory process for the cracking of petroleum in the production of gasoline. It was known at that time that petroleum could be heated in an ordinary cylindrical still under pressure and gasoline would be produced. Unfortunately, in every case a side reaction produced large quantities of coke which were deposited on the bottom of the still. This deposit produced poor heat transfer at that particular point, resulting in a hot spot. In other words, the metal at this point facing the fire would be considerably higher temperature than the surrounding matter. A temperature would finally be reached at which the still could no longer maintain its normal strength. The pressure inside the still would immediately cause a bulge at this point and the still would eventually blow up. The superheated liquid, petroleum, would flash in the fire box with a resulting ex-

plosion which would be disastrous. The industry attempted in a great many ways to overcome this difficulty, but without success. The life of a still runner was becoming shorter and shorter, and the terrain about the refinery was beginnig to resemble no man's land in a movie set-up.

Dr. Burton of the Standard Oil Company of Indiana realized the importance of this situation and attempted to remedy it. He probably reasoned in somewhat this manner, that the factors involved in the reaction were not only pressure, temperature, and concentration, but also the raw material, a particular petroleum fraction, and the final products, gasoline, tar, coke, etc. Most of the other inventors had concentrated their attention on the type of apparatus in which the reaction was to be run and also upon a means of removing the coke as fast as it was formed. Dr. Burton, however, chose for his factor the raw material. He realized that there was a great difference in raw materials. He investigated this situation very thoroughly and finally found a type of oil which could be obtained in large quanities (evidently a paraffin base oil containing no aromatics) which on treatment in the regular manner produced very little or no carbon. This is not all that Dr. Burton did in this particular development, but it serves as an excellent example of the common method of attack used in the majority of our great industrial chemical developments. It might be said that Dr. Burton's cracking process was the first satisfactory commercial cracking process and maintained its paramount position for approximately seven years.

Another interesting example of research in an entirely different line follows this same method of attack. It has been known for some time that pure aluminum would withstand hot gases containing sulfur compounds. On the other hand, pure aluminum has very low tensile strength but would be an excellent thing if we were able to deposit a thin but continuous layer of pure aluminum on steel to be used for industrial purposes where strength and ability to withstand corrosion of certain types are necessary. Probably the most continuous metallic coatings we have today are those produced by the electrodeposition of metals. Unfortunately, aluminum cannot be deposited from the ordinary water solution due to the extreme activity between the aluminum metal and the water. Hydrogen is produced at the cathode. A literature search revealed the fact that a great many different combinations of salts in water solution had been tried in order to deposit aluminum

electrolytically but with no success. Some attempt was made to deposit aluminum from organic solutions with apparently no success.

The subject, however, interested some investigators at the University of Illinois, and it was their belief that the important factor in the reaction was the solvent, or electrolyte. The outstanding characteristic of an electrolyte for successful operation was that it must be free from replacable hydrogen and also have high electrical conductivity. Reasoning from atomic structure, it was thought possible to make a satisfactory electrolyte by using a tetra-alkyl-ammonium-halide in combination with an aluminum-halide. It was also suspected that a compound similar to the Grignard reagent in which the magnesium had been replaced by aluminum might prove satisfactory. These two types of compounds were tried out, and still hydrogen was given off. It was quite evident that the hydrogen did not come from the compounds but from some water present. As the compounds themselves were quite dry, the water must have come from the air above the electrolyte. This air was dried and the reaction, the electrodeposition of aluminum, took place on a copper cathode. The deposit seemed to be a fairly pure aluminum of very fine structure, and adhered fairly well to the copper below.

Another interesting type of industrial chemical research is the development of a new and more satisfactory chemical product to take the place of an old product. An example of this type of development is the well-known rayon, the comparatively new synthetic textile resembling natural silk. Again it is quite possible to outline the common method of attack somewhat as follows:

1. A list of the faults of the old products.
2. A list of similar products not now used for this particular purpose.
3. A selection from list No. 2 of the most suitable product from an economic and common sense standpoint.
4. Modification of this product to eliminate as far as possible what faults it has.

Tincture of iodine is a highly unsatisfactory household antiseptic when applied to open wounds. The content of iodine (seven per cent) is far too great and in many cases it probably does more harm than good because of its tendency to attack living tissue. The solvent alcohol (concentrated) is about as satisfactory a substance to put on a cut as a red hot iron would be. Lastly, tincture

of iodine is usually sold in a bottle with a cork or rubber stopper. Such a package is not exactly a satisfactory thing to carry in one's traveling bag or vest pocket. In brief, this antiseptic popularized by the World War is far from satisfactory for household purposes.

It is well known that both iodine and chlorine have powerful bactericidal action when in the free state. Weight for weight, these halogens are at least seven hundred times as powerful as the corresponding weight of phenol or carbolic acid. It would seem, therefore, that all that is necessary to make a satisfactory household antiseptic is to have a solid compound which when thrown into water would produce dilute solutions of iodine or chlorine (without injurious by-products).

This subject interested some investigators at the University of Illinois, and they decided that the type of solid compound which would prove most satisfactory would be a hypochlorite. After a rather extensive investigation, it was found that a fairly pure calcium hypochlorite containing some excess calcium hydroxide was fairly satisfactory. The liberation of chlorine when this powder was placed in warm water was not rapid enough to satisfy the investigators, so powdered dry aluminum sulphate was added with the calcium hypochlorite. This salt of a weak base produced, in the water solution, free hypochlorous acid which decomposed into chlorine more rapidly and gave quite satisfactory results. Incidentally, an antiseptic of this type can be taken in the form of a dilute solution as a gargle and will have genuine antiseptic properties, something that cannot be said of the majority of mouth washes.

Perhaps the most interesting type of research in applied chemistry or chemical engineering is the development of a new type of machine to do a particular unit operation more efficiently than any standard machine has done it previously. This type of research also can be outlined in a general sort of way as follows:

1. A list of all the basic requirements of the particular unit process.
2. A list of all apparatus used in other industries for a somewhat similar purpose.
3. A selection from list No. 2 of the apparatus which most nearly meets the basic requirements of the process.
4. Modification of this apparatus to meet the special conditions.

Examples of this type of research are very numerous. A few of the outstanding ones might be mentioned: the use of the Haber fixation of nitrogen machine for the manufacture of methanol; the use of mining and metallurgical equipment in the sugar industry; the use of the alcohol fractionating columns in petroleum refining; and the use of the X-ray machine, which formerly has only been used in surgical work, in a thousand different industries.

An interesting recent development at the University of Illinois is the utilization of the homoginizer and colloid mill in the manufacture of acetic acid by the catalytic partial oxidation of ethyl alcohol. It can be predicted, without fear of contradiction, that these two types of equipment will eventually be used in a great many different liquid-gas reactions.

In conclusion, the author wishes to reiterate that modern industrial chemical research is not a mysterious art, but is a highly developed scientific subject. The methods used are almost the same the world over, and the element of luck, though still of great importance, is becoming less and less significant with the passing of time. It might be said that any result desired in industrial chemical research can be had. It is only a question of money, men, and time.

PAPERS IN GEOLOGY

EXTRACT FROM THE REPORT OF THE CHAIRMAN

Besides the eleven papers contributed in the Geology Section, the three papers listed below were read in the meeting but not submitted for publication.

"Contributions from the Winchester Area to the State's Pleistocene History," by A. H. Bell, State Geological Survey, Urbana.

"The Development of Porosity in Limestone," by W. V. Howard, University of Illinois, Urbana.

"Outline of the Geology of the Havana Quadrangle," by H. R. Wanless, University of Illinois and State Geological Survey, Urbana.

After the discussion of the papers, a short business meeting was held in which Fred R. Jelliff, of Galesburg, was elected chairman of the Geology Section for next year.

A. C. NOE', *Chairman.*

A REVIEW OF OUR PRESENT KNOWLEDGE CONCERNING THE CHARACTER AND DISTRIBUTION OF THE PLEISTOCENE AQUATIC MOLLUSCAN LIFE OF ILLINOIS*

FRANK COLLINS BAKER
University of Illinois, Urbana.

Curator, Museum of Natural History, University of Illinois; Consultant in Pleistocene Invertebrate Paleontology, State Geological Survey.

In Volume XX of the Transactions of the Illinois State Academy of Science, page 269, an account was given of the character and distribution of the molluscan life of the Loess deposits in the state. In the present paper a like study is made of the aquatic fauna of the Pleistocene of the state. As in the case of the land mollusks, the recognition of apparently small variations among both recent and fossil forms has added some species and varieties not formerly recognized. The modern study of the effect of the environment in directing evolutionary changes makes the recognition of these apparently minor characteristics necessary.

The fossil record of the aquatic fauna is not as complete as that of the land fauna. This paucity of information is largely due to lack of field work in localities where these deposits occur. It may also be true that some of the lacking species are really absent from the early strata. The tables accompanying this paper indicate in a striking manner the condition of our present knowledge concerning the fresh water fauna of the Pleistocene. Of the 73 species and varieties listed, 12 species or 16 per cent, are believed to be extinct or represented in the recent fauna by different variations of enough diversity to receive distinct names. Nearly all of these extinct forms are believed to be the ancestors of certain species now living in the recent fauna, and the tables show that the change from fossil to recent form has usually taken place in Late Wisconsin time. Many of the species occur in Glacial Lake Chicago deposits and in several forms this change can be seen gradually taking place through the time in which the Great Lakes were evolving in the Chicago region. These changes and the relationships of the fossil to the recent species are mentioned under each species in this paper.

* Contribution from the Museum of Natural History, University of Illinois, No. 56.

The geological distribution of each species during Pleistocene time is interesting and somewhat puzzling. Only eight aquatic species have been seen in deposits referable to Yarmouth time, and none are known from Illinois during Aftonian time. Shimek records 13 species of aquatic gastropods from the Aftonian of Iowa, and doubtless the same number should be found in Illinois. Twenty-six species have been listed as from the Yarmouth interval (see Baker, Life of the Pleistocene, p. 280) but some of the deposits examined may belong to other intervals. Fifteen species are herein recorded from the Sangamon interval of Illinois. Only three species are recorded from the Peorian interval, and these are associated with loess deposits containing land mollusks. Just why there should be this striking paucity of aquatic species in this interval is not apparent, for there were certainly streams and lakes at this time, as at present, in Illinois. It is probable that there is difficulty in accurately placing some deposits which may belong either to the Peorian or to the Sangamon interval. In southern

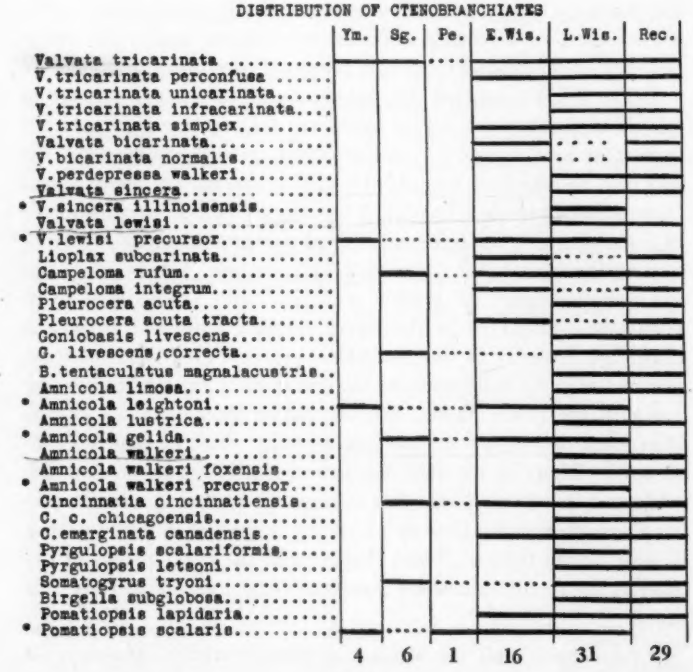

FIG. 1.

and central Illinois this might be the case because of the absence of an Iowan drift sheet or glacial deposit. Great care is needed to work out accurately the stratigraphy of the deposits between the Yarmouth and Early Wisconsin, and many errors have been made in this connection. Some deposits in Ohio and Indiana previously referred to the Sangamon are without doubt of Early Wisconsin age. Accurately determined deposits containing aquatic life from the Sangamon and Peorian intervals are greatly desired, and a comprehensive review of the life of these two intervals is impossible until such material is available.

FIG. 2.

EXPLANATION OF FIGURES

Abbreviations: Ym, Yarmouth; Sg, Sangamon; Pe, Peorian; E. Wis, Early Wisconsin; L. Wis, Late Wisconsin; Rec, Recent. The solid lines indicate the range of the species throughout the different intervals. The dotted line indicates that the species has not been found as yet in this interval, but is likely to be found. The figures at the bottom of the interval columns indicate the number of species at present known from each interval.

With the advent of the Early Wisconsin, aquatic life appears to have flourished abundantly, 29 species being recorded from accurately determined deposits. In the Late Wisconsin this number is more than doubled (68 species), indicating, probably, that conditions were becoming more favorable to the existence of many forms of aquatic life. The rapid jump in the number of species in the later Pleistocene is noteworthy.

A study of the tables at once raises the question as to whether the rapid increase in the number of species from early to late Pleistocene time is in reality an increase in the development of new species and varieties or is simply due to a lack of information. As may be inferred from some of the remarks made previously, a part of the omission is due to lack of information. But there may also be a real development and increase in the number of species and varieties throughout the Pleistocene. It is evident from a study of the recent fauna of the northern states, that there has been a large increase in number of recognizable varieties during recent time; in many cases, river species with but one or two varieties known during the whole of the Pleistocene have developed a dozen or more quite distinct varieties following Late Wisconsin time. This kind of development may have gone on during the entire length of Pleistocene time.

A factor which may be lost sight of in this connection is the possibility of the presence of great lakes comparable to the present Great Lakes system during one or more intervals of the Pleistocene. If there were the same number of smaller lakes, as are now found in Wisconsin and Minnesota, then the fauna may have varied in a like manner. In the Toronto formation in Canada, which Coleman has placed in both the Sangamon and Aftonian intervals, there are 19 species of aquatic gastropods recorded, 14 species of naiades, or river mussels, and seven species of Sphaeriidae. Many of these belong to species now recognized as extinct or belonging to different recent varieties. It will be seen that much more information concerning these early deposits, as they are found in the northern part of the country, is necessary before we are in a position to accurately visualize the aquatic life of the early Pleistocene.

The aquatic life does not tell us much concerning climatic conditions, as does the land fauna. Aquatic life is able to adapt itself to a varying degree of heat and cold, as attested by the present distribution of some species from the Ohio River to middle

Canada, or even the Arctic Circle. In general, many of the species are related to those which enjoy a greater development in the northern part of the United States and Canada, and hence a shifting of the temperature curve northward during recent time is inferred, as well as a southward shift during Pleistocene time, especially during the early and later part of each interval. The middle of each interval may have been quite as congenial as that enjoyed at the present time.

This paper is an attempt to bring together all that we know at present concerning the geological distribution of the aquatic life of the state during the Pleistocene. To insure greater accuracy, only data from undoubted horizons have been used. The tables bring out rather forcefully the places where additional information is needed, and it is hoped that this deficiency in our knowledge may be supplied at an early date. The reasons for the use of the nomenclature herein presented are explained in the recent volumes by the writer issued as Bulletin 70 of the Wisconsin Geological and Natural History Survey, "The Fresh Water Mollusca of Wisconsin." The material used for the present paper was collected by the staff of the Illinois State Geological Survey, and the thanks of the writer are due Dr. M. M. Leighton, Chief of the Survey, for the opportunity of making this study.

FAMILY VALVATIDAE

Four species and eight varieties of this family, all of the genus Valvata, have been recorded from Pleistocene deposits in Illinois. It is noteworthy that but two species, *tricarinata* and *lewisii precursor,* occur as far back as the Yarmouth interval, and that thus far none have been found in Peorian deposits, which appear to contain for the most part species of terrestrial habits. Six species have been seen in deposits of Early Wisconsin age, ten in strata of Late Wisconsin age, and two have thus far been seen only in deposits of Early Wisconsin age. The recent *lewisi* is undoubtedly a direct descendent of the form called *precursor,* and *sincera* would appear to be a recent variation of the variety called *illinoisensis. Valvata bicarinata* doubtless extends far back in the Pleistocene, but its presence in early deposits has not yet been detected.

Valvata tricarinata (Say)

This species is more or less abundant in all intervals excepting the Peorian, and its absence from this interval is probably due

to rarity of aquatic deposits in the region examined. In all of the fossil deposits it is typically tricarinate, exhibiting little variation. Its distribution in Illinois, as at present known, is as follows: *Yarmouth:* Fulton Co.; *Sangamon:* Montgomery Co.; *Early Wisconsin:* Fulton, Gallatin, Champaign Co.; *Late Wisconsin:* Will, Grundy, Iroquois, Kendall, LaSalle, McHenry, and Cook Co.

Valvata tricarinata perconfusa Walker

Typical *tricarinata* is a species of rivers, where it is usually strongly triacrinate. The variations in carination are most marked in the smaller and larger lakes and in the fossils is restricted to the northern part of the glaciated territory. Curiously enough, the variations as known do not appear until the Early Wisconsin interval. The present distribution is as follows: *Early Wisconsin:* Fulton Co.; *Late Wisconsin:* Cook, Will, Grundy, Kendall, McHenry, LaSalle Co.

Valvata tricarinata unicarinata De Kay

Late Wisconsin Interval: Cook, Lake, and Grundy Co., mostly abundant.

Valvata tricarinata infracarinata Vanatta

Known only from the *Late Wisconsin* in Cook, Lake, and Grundy counties. Rare in all deposits.

Valvata tricarinata basalis Vanatta

Not yet observed in Illinois deposits but known from *Late Wisconsin* deposits in Wisconsin near Oconomowoc Lake.

Valvata tricarinata simplex Gould

This ecarinate variety occurs rarely in *Early Wisconsin* deposits (Fulton Co.) and more abundantly in *Late Wisconsin* deposits (Cook, Lake, Grundy, McHenry Co.). In Lake County it is very variable, the upper whorls unusually showing rather distinct carination while the body whorl is quite rounded.

All of the variations are known from adjacent states as far east as New Jersey (White Pond, Sussex Co.). They are especially abundant in deposits in Wisconsin, Michigan, Indiana, and Ohio.

Valvata bicarinata Lea

This species occurs commonly in deposits believed to be of *Early Wisconsin* age in Gallatin Co., near Junction. There is some variation toward variety *normalis,* the lot, in fact, showing every gradation between these two extremes. In the recent fauna,

bicarinata is known from several localities, all in the southern part of the state. Most of these are referable to the variety *normalis,* which, as remarked by Walker, appears to be the normal form of the species.

Valvata bicarinata normalis Walker

Gallatin Co., *Early Wisconsin.* Of 29 specimens found in these deposits, six were *normalis* and 23 *bicarinata.* Among these fossils, the bicarinate form is the more common, reversing the ratios of the recent fauna.

Valvata perdepressa walkeri F. C. Baker

As a fossil this recently described variety is known from two deposits in Chicago, both of *Late Wisconsin* age. These are somewhat smaller than the type form which is so abundant in Lake Michigan on the Illinois side. Excepting in size they are the same as the type form. Neither *perdepressa* nor *walkeri* are known as a fossil earlier than Late Wisconsin time and it is probably a recent offshoot of some river form, perhaps, as suggested by Walker, the *bicarinata* so abundant in the rivers of southern Illinois, where it is also known as a fossil.

Valvata sincera Say

Typical *sincera* has not been found in fossil deposits of Illinois, but specimens referable to the typical form of the species occur in deposits of *Late Wisconsin* age in marl near Oconomowoc Lake, Waukesha Co., Wis. These are like the High Island specimens figured by Walker.

Valvata sincera illinoisensis F. C. Baker

This recently described variety of *sincera* was at first thought to be Walker's *danielsi,* a large form living in Cannon Lake, Minnesota. The abundant material from Illinois, however, indicates that it was erroneously referred to that variety and is, in fact, an ancestral form of *sincera,* characterized by a lengthened spire, rounder whorls, and deeper sutures. It is thus far known from *Late Wisconsin* deposits in McHenry (Crystal Lake, type locality), Cook, and Whiteside counties in Illinois, and from Milwaukee, Green Lake, and Waukesha counties, Wisconsin. The variation is toward the low-spired *sincera* form, which occurs rarely in some lots. The absence of this species and its varieties from deposits earlier than Late Wisconsin is noteworthy, and indicates, if none are found in earlier deposits, that *sincera* is a late species, perhaps the result of lake conditions.

Valvata lewisi Currier

Typical *lewisi* occurs in *Late Wisconsin* deposits in Will, Cook, and Iroquois counties, in all of which it is rare. It also occurs in Waukesha County and near Milwaukee.

Valvata lewisi precursor F. C. Baker

This apparently extinct variety, distinguished by its higher, more scalariform spire, appears to be the ancestor of the recent *lewisi*. It occurs rarely in strata of *Yarmouth age* (Fulton Co.) but has not yet been seen in deposits of *Sangamon* or *Peorian* age. It occurs abundantly in deposits of *Early Wisconsin* age (Fulton, LaSalle, Champaign Co.) and in strata of *Late Wisconsin* age (Waukesha and Green Lake counties, Wisconsin). In Green Lake and Oconomowoc Lake deposits the form is very large with large aperture and here the variation is distinctly toward the recent form of the species, especially as it occurs in western Wisconsin, particularly in the Lake Chetek region of Barron County. Typical *lewisi* is rare in Illinois and has been recorded only from the northern part of the state. The shell with coarse, almost rib-like striae found in New York state is unknown either recent or fossil in Illinois and Wisconsin.

FAMILY VIVIPARIDAE

This family is not well represented in the Pleistocene, if one can judge by the material at hand. Only two species of Campeloma and one of Lioplax have been reported from Illinois, and these do not extend very far back in the period. This is probably due to failure thus far to find deposits of aquatic origin in which this group lived. The total absence of Viviparus is noteworthy.

Campeloma rufum (Haldeman)

This species is fairly common in deposits of *Late Wisconsin* as well as *Early Wisconsin* age. In Iroquois County this species occurred rather commonly in a deposit earlier than Early Wisconsin which is either *Sangamon* or *Peorian,* probably the former. The exact stratigraphy of this section is still to be worked out. In the Chicago deposits, representing the various stages in the formation of Lake Michigan, this species is abundant and variable, appearing between the typical form of rivers and a shorter, more solid variety commonly found in lakes and especially in Lake Michigan. In the Life of the Pleistocene, these are recorded under both *subsolidum* and *integrum,* but all are undoubtedly referable to *rufum.*

Campeloma integrum (Say)

In a ditch near Junction, Gallatin County, a deposit of Mollusca was found which appears to be of *Early Wisconsin* age. This species was represented rather commonly.

Lioplax subcarinata (Say)

A few specimens occurred in strata of *Early Wisconsin* age near Junction, Gallatin County. These are like the species now living in the Saline River and in the Ohio River bordering Gallatin County. It has not been found in other deposits or intervals.

FAMILY AMNICOLIDAE

This large family of fresh water gastropods is well represented in the Pleistocene of Illinois by 15 species and varieties. Ten of these are now living in the recent fauna of Illinois, one is living in Wisconsin, and three are believed to be extinct as far as varieties are concerned. The geological distribution is interesting and especially noteworthy. Only one species is certainly known from the *Yarmouth* interval; three species are known from the *Sangamon* interval; none from the *Peorian* interval; four species are known from the *Early Wisconsin* interval; and all fifteen occur in *Late Wisconsin* time. This broken distribution indicates either that some of the variations are of recent origin or that the record is very incomplete. Both suppositions are probably partly true, for it is possible that many varieties may have arisen since the formation of the lake environments following the retreat of the last ice sheet.

Bulimus tentaculatus magnalacustris F. C. Baker

This wide-spread species appears to have been an inhabitant of the early waters of Lake Michigan, specimens having been found in apparently undoubted deposits of *Late Wisconsin* (Toleston stage of Glacial Lake Chicago) time. For a discussion of the reasons for bestowing a varietal name on the Lake Michigan form of this species, see the Fresh Water Mollusca of Wisconsin, part I, page 88.

Amnicola limosa (Say)

One lot of three specimens of an Amnicola is referred to *limosa*. It has the narrow form and slight umbilicus of the typical form as it occurs in Maryland. The deposit is in La Salle County near Dayton in the Valley of the Fox River, and is of *Late*

Wisconsin age. The absence of this species from strata earlier than Late Wisconsin and its rarity in this late horizon indicates that it may be a late comer in the middle west, possibly a migrant from the eastern part of the country.

Amnicola limosa porata (Say)

As a fossil, both *Amnicola limosa* and its variety *porata* are very rare or absent in the Pleistocene of Illinois, their place being taken, apparently, by *Amnicola leightoni.* In the writer's Life of Pleistocene, the Amnicola from the Chicago deposits were reported as *limosa,* but these are all referable to *leightoni.*

Amnicola leightoni F. C. Baker

This is the common large Amnicola of the Pleistocene. It appears rare in early deposits, only one lot having been seen from the *Yarmouth* interval in Calhoun County. It is known from the *Early Wisconsin* in Gallatin County, near Shawneetown. It is one of the most abundant species in *Late Wisconsin* deposits and is widely distributed. In Illinois it has been collected in Cook, Will, Grundy, Kendall, Lake, and McHenry counties, usually in marl deposits. It is known also from many places in Michigan, Wisconsin, Indiana, and Ohio. This species may be ancestral to the large Amnicola so abundant in Lakes Michigan and Superior, *Amnicola limosa superiorensis* F. C. Baker (see Moll. of Wis., I, p. 101), and if so that form should be considered a race of *leightoni* rather than *limosa. A. leightoni* also resembles some forms of *Amnicola limosa porata* of the lakes of Wisconsin and Michigan, and it may have been ancestral to this race.

Amnicola lustrica Pilsbry

This long-spired species is rare and has been observed in but four deposits in Will and LaSalle counties (*Late Wisconsin*). The specimens differ from the recent form, as it is found in Illinois, only in having a somewhat larger umbilicus and a wider whorl on the average. They are more like the species, as it now occurs in the rivers of Wisconsin. Two recently described varieties of *lustrica* occur in Late Wisconsin deposits in Michigan and Wisconsin, *decepta* and *perlustrica,* but these have not yet been detected in Illinois deposits (see Wis. Mon., I, pp. 108, 109).

Amnicola gelida F. C. Baker

Rare in *Sangamon* interval (Iroquois Co.). Common in *Early Wisconsin* interval (Gallatin Co.). Abundant in *Late Wisconsin*

time, and known from Cook, Will, Kendall, Lake, and McHenry counties. In the Chicago deposits variation is toward a lustrica-like shell, and it might be best ultimately to regard *gelida* as the ancestor of *lustrica* and a variety of the latter. However, as *lustrica* and some of its varieties are also found in Late Wisconsin deposits, and may occur in deposits of earlier date, it appears best to treat *gelida* as a species for the present. Much more material is needed from Yarmouth and Sangamon strata to more clearly interpret these two species. *Gelida* exhibits much variation but, as a whole, is clearly distinct from *lustrica* in the deposits examined. It is known as an abundant fossil in Michigan, Wisconsin, and Ohio, where it is wide-spread over the states. A large species, *Amnicola greenensis* Baker, is known from Green and Oconomowoc lakes, Wisconsin, but this has not yet been detected in Illinois deposits (see Wis. Moll., I, p. 113).

Amnicola walkeri Pilsbry

Common in *Late Wisconsin* deposits in Will County, near Joliet. Also known from deposits in Wisconsin, Michigan, and Ohio, in deposits of the same age. The fossil form is quite typical of the species as it lives in the recent fauna.

Amnicola walkeri foxensis F. C. Baker

One lot from Morris, Grundy County marls (*Late Wisconsin* time) is referable to this recently-described variety, having the narrow form and smaller umbilicus of the Fox River form (see Wis. Moll., I, p. 116).

Amnicola walkeri precursor F. C. Baker

This large, widely-umbilicated variety occurred abundantly in marl beds in McHenry County, at the west end of Crystal Lake (*Late Wisconsin* age). They are exactly like the type form which was found in Green Lake, Wisconsin. It is also known from Waukesha and Door counties, Wis. It is noteworthy that *walkeri* and its varieties are not at present known to occur in deposits earlier than Late Wisconsin. It is a species of the north and may be a late comer in the fauna of the Great Lake region.

Cincinnatia cincinnatiensis (Anthony)

Three lots of an Amnicoloid referred to this species occur in Illinois deposits. One is apparently of *Sangamon* age (Iroquois Co.), one of *Early Wisconsin* age (Sangamon Co.), and one is of

Late Wisconsin age (Chicago deposits). All lots differ from the species as it occurs in the recent fauna, being longer and narrower, with less distinctly shouldered whorls and longer spire. These are possibly to be considered distinct from the typical form, and when more material from widely separated localities and horizons is available it may be thought best to consider them as representing a variety of *cincinnatiensis.*

Cincinnatia cincinnatiensis chicagoensis F. C. Baker

This recently-described variety of *cincinnatiensis* occurs sparingly in the Chicago deposits, one lot from the North Shore Channel near Foster Avenue and one lot from Jeffreys avenue and 75th Street. The individuals from the Pleistrocene deposits (all *Late Wisconsin*) are somewhat smaller than the recent form so abundant in Lake Michigan but are otherwise similar. This variety is without doubt an offshoot of the river species *cincinnatiensis* which is abundant in Illinois and states south and east. In the recent fauna the shells vary from almost as long-spired as *cincinnatiensis* to a form so globose that height and diameter are equal. This variety began to change in the more open waters of Glacial Lake Chicago and finally developed into the large form so abundant in the western part of the lake.

Vancleaveia emarginata canadensis F. C. Baker.

The northern variety of *emarginata* has been detected in three Pleistocene deposits; one of *Early Wisconsin* age (Gallatin Co.), and two of *Late Wisconsin* age (LaSalle County and Chicago deposits). The Gallatin and LaSalle County specimens are like those from the Mackenzie River, but the Chicago deposits contain material varying toward the typical river form. It is surprising that no material representing the typical river form has been found as yet in Pleistocene deposits in Illinois or adjacent states. The variety still lives in Lake Michigan in great abundance and the fossil material from the Chicago deposits indicate a variation from a smaller, more typical form to the large umbilicated Lake Michigan variety.

Pyrgulopsis scalariformis (Wolf)

Known from two Pleistocene deposits in Illinois, Tazewell County on the Illinois River and Rock Island Co., near the Mississippi River. Neither of these deposits has been stratigraphically examined, and it is not yet known from what interval the speci-

mens came. The species is not now living in Illinois, but the same, or a closely related species, has been found in Shoal Creek, Alabama. There is reason to believe that the recent form should be considered a variety of *scalariformis.*

Pyrgulopsis letsoni (Walker)

This small species occurs only in the Chicago deposits and is hence a species of *Late Wisconsin* time. A related form now living in several places in Michigan should probably be considered a variety, having the whorls much rounder with deeper sutures and a more rounded aperture. The typical form is not now living in either Illinois or Wisconsin.

Somatogyrus tryoni Pilsbry & Baker

This species, first observed in the recent fauna near Milwaukee and later in abundance in Rock River, Wis., also occurs in Pleistocene deposits. In Iroquois County near Milford, it occurred in strata believed to be of *Sangamon* age and was also found living in Sugar Creek. The material differs in no wise from the species as it occurs in Rock River and elsewhere in Wisconsin. Four specimens were also found in material from Flat Rock River, Bartholomew Co., Indiana, in deposits believed to be of *Early Wisconsin* age. The occurrence of this species in the mid Pleistocene indicates a long period of existence without change. It will doubtless be found in other, possibly still earlier, deposits in this and other states.

Birgella subglobosa (Say)

This species occurs more or less commonly in the Chicago deposits (*Late Wisconsin* age). It has been found, though rarely, as a recent species in Lake Michigan, these being the lineal descendents of the forms living in old Glacial Lake Chicago. Curiously enough, no representatives of this species, or of its river form *isogona,* have been found in any other Pleistocene deposits as yet examined. The river form is rather abundant in parts of Illinois and it should be found as a fossil.

FAMILY POMATIOPSIDAE

Two species of this amphibious family of gastropods occur in the Pleistocene deposits of Illinois. Another species, *Pomatiopsis cincinnatiensis,* occurs in Indiana, but has not yet been found in Illinois, although it occurs in the recent fauna. The species

scalaris is abundant in loess and other deposits as far back as Yarmouth time and probably extends backward into Pliocene time. The advent of *lapidaria* in Early Wisconsin time and the final dying out of *scalaris* in Late Wisconsin time are of interest in the study of the evolution of species in geological time.

Pomatiopsis lapidaria (Say)

Occurs in Fulton Co. (*Early Wisconsin*) and Stephenson Co. (*Late Wisconsin*) in loess deposits. Early Wisconsin specimens vary somewhat toward the *scalaris* form of shell.

Pomatiopsis scalaris F. C. Baker

Occurs more or less abundantly in the following intervals, usually associated with loess deposits: *Yarmouth* interval (Clark, Sangamon, Fulton, Effingham, and Madison counties); *Peorian* interval (Fulton Co.); *Early Wisconsin* interval (Fulton Co.); *Late Wisconsin* time (Will Co.). The species as a whole is remarkably uniform in the long, scalariform spire and open umbilicus. It is obviously closely related to *lapidaria* and is without doubt the ancestor of that species.

FAMILY PLEUROCERIDAE

Two species and two varieties of this family occur in the Pleistocene of Illinois, as far as now known. The evidence indicates that they are for the most part late comers, and while this is probably true as regards the lake forms, it should not be the case with the river forms, which have doubtless existed far back into the Pleistocene or even the Pliocene. Goniobasis is known from the Sangamon interval. The record is obviously quite incomplete.

Pleurocera acuta Rafinesque

Typical *acuta* occurs rarely in the Chicago deposits (*Late Wisconsin*) and is also found living in the recent fauna of Lake Michigan.

Pleurocera acuta tracta (Anthony)

This river variety of the lake form listed above occurs abundantly in two deposits of *Early Wisconsin* age, Gallatin County near Junction and Champaign County near Mahomet. The shells vary from almost smooth to heavily spirally lined, especially below the periphery. The Gallatin County shells are larger than those from Mahomet.

Goniobasis livescens (Menke)

Common in the Chicago deposits. Variable, but mostly with long spire characteristic of the typical form. The Lake Chicago form now lives in Lake Michigan.

Goniobasis livescens correcta (Brot)

Three lots of a Goniobasis are referable to this river variety, one in the *Sangamon* interval (Iroquois Co.) and two in *Late Wisconsin* time (Will County). All are rather small specimens of the variety.

FAMILY LYMNAEIDAE

Thirteen species and varieties of this family occur in the Pleistocene of Illinois. Of these, only four are known from intervals earlier than Late Wisconsin time; three are known from the *Yarmouth,* three from the *Sangamon,* two from the *Peorian,* and five from the *Early Wisconsin.* Just why some of these species have not yet been found in earlier strata is not now apparent. It is evident that much more field work is necessary before a complete account can be written of the geological history of this, as well as of other families of fresh water mollusks in Illinois.

Lymnaea stagnalis jugularis Say

More or less common in *Late Wisconsin* deposits in Cook, Will, and McHenry counties. The fossil *jugularis* does not differ in any particular from the species as it is found in the recent fauna. It is possible that this large Lymnaea is a post-Wisconsin migrant from the northwest, the only place where it could find refuge in suitable habitats during the glacial conditions. Possibly Lymnaea *stearnsi* Hannibal (*maxima* Stearns), a middle Miocene species, may be an ancestor. It is significant that no material earlier than Late Wisconsin time has been thus far seen in the Pleistocene of the middle west.

Stagnicola palustris elodes (Say)

Common in *Early Wisconsin* deposits in Fulton Co., and in *Late Wisconsin* deposits in Cook, Will, and Whiteside counties. The fossil examples are like those now living. It is worthy of note that no material has yet been found in deposits earlier than Early Wisconsin time.

Stagnicola umbrosa (Say)

A single lot of this species occurred in the Chicago deposits, *Late Wisconsin* time.

Stagnicola umbrosa jolietensis (F. C. Baker)

One specimen from the Joliet marls (Will Co.) is exactly like the recent variety, which was first observed near Joliet. *Late Wisconsin* time.

Stagnicola reflexa (Say)

Sangamon time, Montgomery Co., rare; *Early Wisconsin* time, Champaign Co., abundant; *Late Wisconsin* time, Cook, Grundy, and Iroquois counties. The fossil forms are like the species of the recent fauna. It is noteworthy that this species, so abundant and typical in the recent Illinois fauna, was also abundant during a large part, if not the whole, of the Pleistocene.

Stagnicola woodruffi (F. C. Baker)

Occurs rarely in the Chicago deposits (*Late Wisconsin* time). There is some variation in length of spire, as in the recent fauna, but all are characteristically *woodruffi*. The species apparently evolved about the mid-Glacial Lake Chicago stage. More fossil material would help in tracing the ancestry of this peculiar species, which is one of the most characteristic of the recent fauna. *Woodruffi* is apparently an offshoot of *catascopium*, but none of the latter are known from fossil strata in Illinois, and the species is doubtful as a recent species of the Illinois fauna. *Catascopium* is known from Pleistocene (Late Wisconsin) deposits in Wisconsin and Michigan. Material from Oconomowoc Lake marls is exactly like Currier's *intertexta*, and it is probable that that name should be used for some of the lake varieties in the recent fauna and also for the fossil forms mentioned, as well as some from other places.

Stagnicola caperata Say

Yarmouth interval (Fulton Co.); *Sangamon* interval (Fulton Co.); *Peorian* interval (Carroll, Fulton, Whiteside counties); *Early Wisconsin* interval (Fulton and Champaign counties); *Late Wisconsin* time (Cook and Will counties). The *caperata* in the early Pleistocene is on the average shorter and wider than in the recent fauna, and the material from Late Wisconsin time is more like the recent than the earlier Pleistocene forms. The occurrence in loess deposits with land mollusks is interesting and is due to their amphibious habits and their ecological environment in ephemeral pools which become dry in summer and fall.

Acella haldemani ('Desh. 'Binney)

A few specimens of this narrowest of the Lymnaeas occurred in a marl deposit in Joliet, Will Co. It is known from Cedar Lake, Lake Co. in the recent fauna. This species would appear to be a recent addition to the molluscan fauna, judging by its absence from earlier strata.

Fossaria parva tazewelliana (Wolf)

Yarmouth interval (Clark, Bureau, Fulton, Madison, and Sangamon counties; *Sangamon* interval (Iroquois Co.); *Peorian* interval (Fulton, Mercer, Sangamon, Carroll, Whiteside counties); *Early Wisconsin* interval (Fulton County); *Late Wisconsin* time (Will, Fulton, Whiteside counties). As a whole, *tazewelliana* is constantly different from the recent *parva* in its narrower shell and longer spire. Certain material from Carroll and Whiteside counties (Peorian interval) vary strongly toward *parva* and taken alone would probably be referred to that type. Recent material from Iowa more nearly resembles the fossil form than do individuals from Ohio, the state type locality. *Tazewelliana* is more often found in loess deposits associated with typical land mollusks than in any other strata. Its habit of living on wet mud along stream margins subject to loess accumulation accounts for its inclusion in this material.

Fossaria dalli grandis Var Nov.

The *Fossaria dalli* of the Pleistocene is uniformly larger, with five to 5½ full whorls, the sutures deeper and the whorls rounder, the whole shell wider, the aperture longer and narrower. The type specimen measures: L. 4.5; W. 2.4; Ap. L. 2.3; W. 1.3 mm. (No. P372a, Mus. Nat. Hist., collected by J. H. Ferris from marl beds in the Fair Ground in Joliet, Will Co. *Late Wisconsin* age). Referable to this variety are also specimens from the *Yarmouth* interval (Clark Co.), and three deposits in the *Late Wisconsin* (Carroll, Will, and Whiteside Co.). All are uniformly larger than the recent form, which only rarely attains any such proportions in length, and never in width and general size. The recent *dalli* is undoubtedly the descendent of the larger Pleistocene variety.

Fossaria obrussa (Say)

Typical *obrussa* occurs somewhat sparingly in four deposits of *Late Wisconsin* time, in Cook, Will, McHenry, and Stephenson counties. In all of these it is typical of the species as it now lives

in the recent fauna. None have been seen from deposits earlier than Late Wisconsin.

Fossaria obrussa decampi (Strong)

Early Wisconsin deposits (Champaign and Fulton counties); *Late Wisconsin* deposits (Cook, Grundy, McHenry counties). This variety of *obrussa* is one of the most abundant fossils of the Pleistocene. It varies greatly, and the material of the Pleistocene parallels the variations of the recent fauna. It also occurs abundantly in marl deposits in Michigan, Wisconsin, Indiana, and Ohio. No examples of the variety have been seen from strata earlier than Early Wisconsin.

FAMILY PLANORBIDAE

Fourteen species and varieties of this family have been determined from Pleistocene deposits in Illinois. All are known from Late Wisconsin strata, and there appears to be a greatly decreasing ratio as we go backward in time. Six species only are known from Early Wisconsin time, none are known from the Peorian, five occur in Sangamon time, and but one species, the common *Gyraulus altissimus,* is known from Yarmouth time. A part of this disparity in species representation is due to defective records, but a part may also be due to actual absence from the geological interval. Of the 14 species, four are believed to be extinct, or to be replaced by different varieties in the recent fauna.

Helisoma antrosa (Conrad)

Late Wisconsin time (Joliet, Will Co., LaSalle Co., in marl). Several specimens of *antrosa* appear referable to the typical river form in the lots mentioned. They have a wider umbilicus, and the dorsal carina is nearer the outer edge of the body whorl than in *striata.*

Helisoma antrosa striata (F. C. Baker)

This characteristic Pleistocene Helisoma has been seen in the following deposits in Illinois: *Sangamon* (Iroquois Co.); *Early Wisconsin* (Gallatin and Champaign counties); *Late Wisconsin* (Cook, Will, Grundy, Kendall, LaSalle, Lake, and McHenry counties). It is also known from Wisconsin, Michigan, Ohio, Indiana, and New Jersey, indicating that the variety was wide-spread in Pleistocene time. The chief characteristic of this apparently extinct variety is the small umbilicus and the heavy, centrally placed dorsal carina. The spiral striation is usually very strong in

fossil shells, but in some lots there is variation from no striation to a condition in which these lines are raised into ridges. The descendent of *striata* is the *Helisoma antrosa sayi* F. C. Baker, which is abundant in lakes in Wisconsin, Michigan and Minnesota, as well as in Canada. This form is higher axially, has a somewhat smaller umbilicus, and the dorsal carina is not as heavy and is placed nearer the outer edge of the body whorl. In Pipestone Lake, Cass County, Michigan, *striata* varies toward the lake *sayi* form. *Striata* apparently lived in rivers and streams, for in Iroquois County the *antrosa* of the Sangamon deposit is undoubted *striata* while the form living in Sugar Creek is typical *antrosa*. *Antrosa* is a splendid example of the effect of the Glacial Period on a species. The typical form is a river species not varying to any great extent. In the lake regions of the glaciated area, there are now no less than ten varieties, showing how evolution progresses when a species enters a new kind of environment.

Helisoma trivolvis (Say)

Sangamon interval (Montgomery Co., in silt); *Late Wisconsin* time (Cook, Will, Grundy, McHenry, LaSalle, and Henry counties). *Trivolvis* in Pleistocene deposits varies little from the species as it is known in the recent fauna.

Helisoma pseudotrivolvis (F. C. Baker)

Cook, Will, Grundy counties, all *Late Wisconsin* time. One lot from the University Campus, Champaign Co., is from *Early Wisconsin* deposits. This species is now living in Salt Fork, Urbana, Champaign Co., the type locality. The fossil forms are as characteristic as are the individuals of the recent fauna. None have been seen from earlier deposits.

Helisoma campanulata (Say)

Material referable more or less to the typical form of this species has been found in deposits in Kendall, McHenry, Lake, and Will counties. All are referable to *Late Wisconsin* time. Some of the material varies toward the variety called *ferrissi*, as in the Chicago and Lake County deposits. No fossil examples of *campanulata* have been seen in strata earlier than Late Wisconsin.

Helisoma campanulata ferrissi (F. C. Baker)

This apparently extinct variety of *campanulata* has been seen in one deposit of *Early Wisconsin* time (Champaign Co.) and in

three deposits of *Late Wisconsin* time. *Ferrissi* is a form with less axial height than the larger typical form and the whorls are somewhat more tightly coiled. In many lots of recent *campanulata* there are individuals which could be referred to *ferrissi,* but no lots including all of the fossil type have been seen. The variation in the *campanulata* from the Chicago deposits is toward a *ferrissi* shell, and it is to be presumed that the fossil is a variant of the typical form, but whether *ferrissi* is ancestral to *campanulata* cannot at present be determined for lack of material from earlier deposits.

Planorbula indianensis F. C. Baker

Sangamon interval (Montgomery, Fulton, Iroquois counties); *Late Wisconsin* time (Chicago deposits, Cool Co.). This recently distinguished species is apparently extinct, nothing approaching it having been seen from the recent fauna. It resembles *armigera* but is larger, with a greater axial height and five full whorls. In size it is between *armigera* and Dall's *chrystyi,* a recent species of northern distribution. This species has six full whorls and is different from *indianensis.* The absence of *indianensis* from deposits between Sangamon and Early Wisconsin, and from the earlier Yarmouth interval is noteworthy. The type locality is in a deposit near Mt. Vernon, Indiana, beneath a terrace believed to be of Early Wisconsin age. It is thus either Peorian or Sangamon in age. In a deposit in Iroquois Co., the fossil species from Sangamon strata is *indianensis,* while the species living near Sugar Creek at the present time is *armigera.*

Menetus exacuous (Say)

Late Wisconsin time (Will, Grundy, and McHenry counties, in marl deposits). All typical.

Menetus exacuous megas (Dall)

Late Wisconsin time (Cook, Will, Lake, and McHenry counties, in marl deposits). This variety, known by the sharp, pinched nature of the peripheral keel, is rarely represented. It is worthy of note that no *exacuous* of any kind has been found as yet from deposits earlier than Late Wisconsin. Both the typical form and the variety *megas* are more or less common in Late Wisconsin strata of Wisconsin, Michigan, and Ohio.

Gyraulus deflectus (Say)

Late Wisconsin time (Chicago deposit and Joliet). In both deposits the form is not quite typical but varies toward *obliquus.*

Gyraulus deflectus obliquus (DeKay)

Abundantly distributed in Illinois, in deposits of *Late Wisconsin* age, principally (Cook, Will, Grundy, Kendall, McHenry, Lake Co.) Obtained also from one deposit of *Sangamon* age in Iroquois Co. Widely distributed in Late Wisconsin deposits in Wisconsin, Michigan, Indiana, and Ohio. In the fossil form of *obliquus* there is great variation toward the typical *deflectus* with the acutely keeled periphery, especially in some of the material from the Chicago deposits. The same variation obtains among recent material of this variety. Its rarity in deposits earlier than Late Wisconsin, excepting in one instance, is to be explained only by rarity of material.

Gyraulus altissimus (F. C. Baker)

Yarmouth interval (Fulton, Clark, Menard Co.); *Sangamon* interval (Iroquois, Montgomery, Boone Co.); *Early Wisconsin* interval (Fulton, Gallatin, Champaign Co.); *Late Wisconsin* time (Cook, Will, Grundy, Iroquois, Kendall, LaSalle, Lake, McHenry Co.). This is the commonest and most widely distributed species of the family in Pleistocene time. It is very distinctive and does not appear to vary toward any other species. Its large size and flat-sided whorls, in addition to the reamed-out character of the base, will usually easily determine it. This species is related to the recent *arcticus,* differing in having four full whorls (*arcticus* has but 3½ whorls) and in its flatter and more excavated base (*arcticus* has the basal whorls rounded). As far as at present known, all references to *altissimus* from the recent fauna refer to *arcticus.* No true *altissimus* has been seen from the recent fauna. A form of *arcticus* occurs in Georgian Bay and vicinity which has been identified as *altissimus,* but while it has somewhat the same base, there are but 3½ whorls, and the characters are those of *arcticus* and not *altissimus. Altissimus* appears to replace *parvus* in the Pleistocene of the Middle West; only one lot of fossils that in any way approach the recent *parvus* has been seen, and this was from what are believed to be Early Wisconsin deposits in Bartholomew County, Indiana, on Flat Rock River. *Altissimus* is widely distributed in Late Wisconsin deposits in Wisconsin, Michigan, and Ohio. The *Planorbis arcticus* recorded in Trans.

Ill. Acad. Sci., XV, p. 412, proves to be a form of *altissimus*. Thus far, no true *arcticus* has been seen from Pleistocene deposits. It is surmised that *altissimus* is ancestral to *arcticus*.

Gyraulus circumstriatus (Tryon)

Planorbis parvus urbanensis **F. C. Baker, Nautilus, XXXII, p. 94, 1919.**

This very distinct species has been overlooked for many years, but proves to be widely distributed, both living and fossil. The species *urbanensis* was founded on small and immature specimens of the larger recent form. Its geological distribution, as at present known, is: *Early Wisconsin* interval, Champaign County, University of Illinois campus; Fulton County, Isabel Township; *Late Wisconsin* time, McHenry County, near Crystal Lake, Cook Co., Chicago deposits, Joliet, Will Co., in marl. (See Wis. Mon., I, p. 378 for a discussion of this species.)

Gyraulus crista (Linn.)

This smallest of the Planorboids is often overlooked on account of its diminutive size, which may account for its apparent rarity. Material has been seen from *Early Wisconsin* deposits (Fulton County) and *Late Wisconsin* deposits (Will County). The fossil material is like the form now living in the recent fauna.

FAMILY ANCYLIDAE

The fresh-water limpets are but poorly represented in the Pleistocene. Much of this paucity of material is doubtless due to their being overlooked in collecting and sorting specimens in the field. However, the total absence of any member of the group from deposits earlier than Late Wisconsin is peculiar and difficult to account for. The family dates back to the late Tertiary and certainly must have been present in the American Pliocene. Additional material will be looked for with interest. Only four species have been seen from fossil deposits in the Middle West.

Ferrissia paralella (Say)

Rare in marl deposits in Cook, Will, and McHenry counties (*Late Wisconsin*). Also known from Michigan, Wisconsin, and Ohio, in marl deposits. The specimens are quite typical.

Ferrissia kirklandi (Walker)

A few specimens of this species occurred in a marl deposit in Lake Co., six miles north of Barrington. *Late Wisconsin.*

Ferrissia fusca (C. B. Adams)

A few specimens from the Chicago deposits. *Late Wisconsin.*

Ferrissia tarda (Say) occurs in marl deposits in Bartholomew County, Indiana, near Flat Rock River. These have a very high spire. The deposit is thought to be of *Early Wisconsin* age.

FAMILY PHYSIDAE

Six species and one variety of this family have been identified in the Pleistocene of Illinois. Only two of these occur in strata older than Late Wisconsin. One, *Physella gyrina hildrethiana,* is the only Physoid thus far found in early Pleistocene deposits in Illinois (in the Sangamon). The family must have been represented throughout the Pleistocene, and this scarcity or absence of the group from so many early deposits is rather puzzling. As in other groups, this is apparently due to lack of detailed work in places favorable to the preservation of this type of shell.

Physella sayii (Tappan)

This characteristic Physoid occurs in several deposits of *Late Wisconsin* time (Lake, Cook, and McHenry counties). It is also found in Wisconsin and Michigan, mostly in marl deposits of Late Wisconsin age. It varies greatly with age, young individuals having a short spire and wide body whorl, somewhat resembling some forms of *ancillaria.* Adult shells, however, have a long, pointed spire and are exactly like specimens in the recent fauna from Ohio, Michigan, and Wisconsin. That it has not thus far been found in deposits earlier than Late Wisconsin is interesting, but the record is probably not complete.

Physella gyrina (Say)

This common and variable species occurred in three marl deposits of *Late Wisconsin* age (Will, Cook, and LaSalle counties). These specimens are like material of the recent fauna from southern Illinois. There is considerable variation in the form of the spire.

Physella gyrina hildrethiana (Lea)

The swamp and marsh variety of *gyrina* appears to be more abundant than the typical form. Several immature specimens from near Litchfield, Montgomery Co., are referable to *Sangamon* time. In the deposit on the University campus, Champaign Co. (*Early*

Wisconsin) it is very abundant. In *Late Wisconsin* deposits, mostly peat, it has been found in Cook, Will, Grundy, and Iroquois counties. It is abundant in the Chicago deposits of Glacial Lake Chicago.

Physella integra (Haldeman)

Known at present only from deposits of *Late Wisconsin* age (Cook, Will, Lake and Kendall counties). The material is very variable, from very short to very long spired. This variation is especially marked in the Chicago deposits, where, doubtless, there was marked evolution as the environment changed from river to lake type. Many forms simulate the short-spired forms now living in Lake Michigan which have been named *billingsi* and *brevispira*. *Integra* is abundant in marl deposits of *Late Wisconsin* age in Wisconsin and Michigan, where the spire variation is also very marked.

Physella walkeri (Crandall)

Some material from *Late Wisconsin* deposits (Cook and McHenry counties) appears referable to this species, having a narrow shell and long spire. Two small specimens from an *Early Wisconsin* deposit (Fulton Co.) are also referred to this species, which appears to be rather rare in Pleistocene deposits.

Physella michiganensis (Clench)

A small Physa, nearer this recently-described species than any other, occurred in two deposits of *Late Wisconsin* time. At first it was thought to be Lea's *anatina*, but it is smaller and the spire is not quite as long. Lea's species, also, is a more southern one, *michiganensis* apparently taking its place in the northern states.

Aplexa hypnorum (Linn.)

A single lot of this species was found in a deposit in Carroll Co. (*Late Wisconsin* time). All were young but undoubtedly this species. The apparent scarcity of this species in Pleistocene deposits is striking and may indicate that it is a comparatively recent addition to the United States fauna.

SHORE RECESSION IN SOUTHEASTERN WISCONSIN

JOHN R. BALL AND WILLIAM E. POWERS

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During April, 1929, frequent mention has been made in the daily press of the high water conditions in several of the Great Lakes. On April 12, 1929, Chicago Sanitary District engineers found the level of Lake Michigan 582.34 feet A. T. This is 3.42 feet higher than the average level in 1927, which was reported as 578.96 feet A. T. The higher water, alone, probably would attract but little attention, but the frequent severe storms during the present spring have caused exceptionally heavy wave action on the shores of Lake Michigan and of others of the Great Lakes. Damages amounting to more than $1,000,000 in a single storm were reported from Chicago and vicinity. The entire sweep of the west shore of Lake Michigan and the south shore of Lake Erie have been affected especially by the repeated storms. The obvious results of this erosion are evident in fresh slumps, fallen trees, and wave-swept beaches visible in many places along the Lake Michigan shore. That considerable material has been shifted in these storms is indicated in the newspaper statement that in Evanston, Illinois, 40,000 tons of sand, dumped near the lake and to be used in construction work, were entirely removed in the storm of April 2, 1929. Similar changes during storms have been reported for earlier dates from Kenosha, Wisconsin.

With wide-spread attention thus directed to the wasteful work of the waves, this seems an opportune time to present certain quantitative results of the energy expended. The purpose of this report is to bring into one summarization the data on this subject that have been accumulating for more than 60 years. Some additional measurements have been recorded since reference to this erosion was last published in 1920.[1] Valuable data have been contributed by Mr. W. E. O'Brien, City Manager of Kenosha, Wisconsin.

The western shore of Lake Michigan, in the southern part of the basin, is composed of three general types of material: glacial

[1] Ball, J. R., "The Intercision of Pike River, near Kenosha, Wisconsin," Trans. Ill. Acad. Sci., Vol. XIII, 1920, pp. 323-326.

till or boulder clay, stratified clays and sands of lacustrine origin, and bedrock. A fourth material is eolian sand, but it forms the shore at but few places where recession is occurring. In the area under consideration, bedrock forms the shore at only one known place—Wind Point, four miles north of Racine. The greatest resistance to erosion is possessed by the bedrock that forms at Wind Point a projecting salient. The least resistance to erosion is offered by the lacustrine deposits, especially where the shores are low. High cliffs of hard till or boulder clay are eroded with greater difficulty.

The results of wave erosion have been: first, the cutting away of the ancient lacustrine plain of the higher lake stages along 69 of the 153 miles of coastline from Evanston, Ill., to Manitowoc, Wis.; and second, the general development throughout most of this distance of a high cliff and wave-cut platform.

The shore recession in the southern Lake Michigan basin was noted as early as 1864 by Charles Whittlesey,[2] and very soon after that by Henry M. Bannister. Whittlesey compared the rate of wave erosion in clay and sand deposits at Milwaukee with that in similar deposits at Cleveland, where he calculated the average annual recession to be 5.54 feet. Whittlesey further observed that wave erosion is least effective in the low lake stages, when beaches are broad and protect the cliffs behind them.

Bannister in 1868 made the following statement concerning the ancient beach ridges of that part of the Chicago plain on which northern Evanston and Wilmette are situated:[3] "The ridges which are cut off by the lake strike the shore at a small angle, and from their direction we are able to judge the trend of the coast in former times, and it appears that a large territory, probably many square miles in extent, has been washed away by the wearing action of the lake waves. At the present rate of wear, which at the greatest estimate, and at the most exposed points, is but a few feet annually, it must have taken many hundreds and even thousands of years to wear away this territory, the lake being at or very near its present level." Two years later Bannister[4] called attention to the wave erosion just south of Waukegan, Illinois, where the bluff, unprotected in some places by a beach, was being rapidly under-

[2] Whittlesey, Charles, "Fresh-Water Glacial Drift of the Northwestern States," Smithsonian Contribution 197, 1864, p. 27.
[3] Bannister, Henry M., "Geology of Cook County," Ill. Geol. Surv., Vol. III, 1868, p. 242.
[4] Bannister, Henry M., "Geology of McHenry and Lake Counties," Ill. Geol. Surv., Vol. IV, 1870, p. 127.

mined and carried away. The actual rate of erosion Bannister did not determine, but he judged "that in the course of years it might be considerable, amounting perhaps to several hundred feet in a century."

The first comprehensive quantitative measurement on the rate of shore recession in this region were compiled and published by Andrews[5] in 1870. Chamberlain[6] in 1877 published the results of measurements made respectively by Dr. P. R. Hoy, S. G. Knight,

TABLE I—EARLIER DATA ON SHORELINE RECESSION.

Observer	Period	Locality	Total observed recession	Average annual recession
Andrews	15 to 35 years preceding 1870	23 points between Evanston and and Manitowoc		5.28 ft.
Hoy	1840-1884	Racine cemetery	6.82 acres along 921 feet of shore	9.73 ft.
Knight	1836-1874	18 section and quarter-section lines in Racine County	126.72 ft. (mean)	3.33 ft.
Chamberlin	1835-1874	8 section lines in in Milwaukee County	103.80 ft. (average)	2.77 ft. (mean)
Galvin	41 to 57 years following 1928	8 points in Berrien County, Mich.	152.36 ft. (average)	3.30 ft. (mean)

and himself. In 1899 Leverett[7] published the results of measurements made by Mr. Glavin, at one time Surveyor of Berrien County, Michigan. Table I is a summary of the results of the five men mentioned.

The measurements in Table I are all taken over periods of time sufficiently long to include both high and low lake stages and, therefore, times of both rapid and slow wave erosion. At times of high water level, erosion is surprisingly rapid, as shown by certain measurements made in 1905 to 1907 at Manitowoc by

[5] Andrews, Edmund, "The North American Lakes Considered as Chronometers of Post-Glacial Time," Trans. Chicago Acad. Sci., Vol. II, 1870, pp. 1-24.
[6] Chamberlin, T. C., "Geology of Wisconsin," Vol. II, 1877, pp. 219-233.
[7] Leverett, Frank, "The Illinois Glacial Lobe," U. S. G. S. Mon. XXXVIII, 1899, p. 458.

Goldthwait.[8] Here a low cliff in soft lacustrine deposits was pushed back at a rate of more than 40 feet per year during the period mentioned. For that interval the mean level of Lake Michigan was between 581 and 582 feet.

Since the publication of the figures set forth above, certain measurements have been made in the vicinity of Kenosha, Wisconsin, by Mr. W. E. O'Brien and the senior author of this paper. Mr. O'Brien, in 1922, had occasion to resurvey certain section and quarter-section lines that intercept the line of the Great Lakes Survey in 1835. The results of his work are set forth in Table II.

TABLE II—MEASUREMENTS BY W. E. O'BRIEN IN TWP. 1 NORTH, RANGE 23 EAST (SOUTH OF KENOSHA).

Location	Total recession, 1835-1922	Average Annual recession
N. line Sec. 32	655 ft.	7.64 ft.
Quarter-section line, Sec. 29	670 ft.	7.70 ft.
N. Line Sec. 29	552 ft.	6.33 ft.
Quarter section line, Sec. 20	675 ft.	7.76 ft.
N. line Sec. 20	480 ft.	5.52 ft.
Quarter-section line, Sec. 17	529 ft.	6.08 ft.
Average	595 ft.	6.84 ft.

Along this stretch of 2½ miles, the loss in acres for the period mentioned was 180.29.

In 1918 the senior author established north of Kenosha several lines which he remeasured in 1921 and again in 1929. During this period most of his original markers (the "trees" mentioned below) were lost in the rapid recession of the shore. Tables III and IV give his records of cliff recession as indicated by those markers which still remain.

The striking contrast between the rate of recession indicated in Table III and that in Table IV is explained by the lake levels at these two periods. In 1917 and 1918 the level of Lake Michigan exceeded 582 feet[9]; in 1919 and 1920 it exceeded 581 feet. The drop in elevation continued until 1927, when the mean level was less than 579 feet. During 1928 and 1929 the lake again has risen

[8] Goldthwait, James W., "Abandoned Shorelines of Eastern Wisconsin," Wis. Geol. and Nat. Hist. Surv., Bull. 17, 1907, p. 58.
[9] Henry, Philip W., "The Great Lakes-St. Lawrence Waterway," Geog. Review, Vol. XVII, 1927, pp. 258-277.

to a level of more than 581 feet, and the waves now are strongly attacking the cliff at the several points mentioned in Tables III and IV. It appears, therefore, that any trustworthy figures on the average rate of shore recession must cover a period of time sufficiently long to cover both high and low lake stages.

TABLE III—MEASUREMENTS IN TWP. 2 NORTH, RANGE 23 EAST, NORTH OF KENOSHA, FOR THE PERIOD 1918-1921.

Station	Location	Total recession	Annual recession
Tree 1	S. line Sec. 19	29 ft.	9.67 ft.
Tree 2	3 rods N. of Tree 1	33 ft.	11.00 ft.
Tree 3	N. line SE¼ of SE¼ Sec. 19	41 ft.	13.67 ft.
Tree 4	35 rods N. of Tree 3	45 ft.	15.00 ft.
	Average	37 ft.	12.33 ft.

TABLE IV—MEASUREMENTS IN THE SAME LOCALITY, FOR THE PERIOD 1921-1929.

Station	Location	Total recession	Annual recession
Tree 2	See Table III	3.2 ft.	0.4 ft.
Tree 4	See Table III	8.5 ft.	1.06 ft.
	Average	5.85 ft.	0.73 ft.

Interest in the shore recession naturally centers about two topics: the actual loss of property and the physiographic changes. If the average recession, before breakwaters or "groins" were built to retard it, was 3.5 feet per year between Evanston and Manitowoc, the land destroyed must have amounted to 64.9 acres per year, or more than ten square miles per century. Further, if in a year of exceptionally rapid erosion a recession of 12.33 feet should occur between Kenosha and Racine, the land destroyed would amount to 15 acres. If this land is worth $1,000 an acre the property loss would amount, therefore, to $15,000 in a year along a section of coast only ten miles in length.

The physiographic development of most interest has been the peculiar modification of drainage known as "intercision."[10] Pike

[10] Goldthwait, James W., "Intercision, a Peculiar Modification of Drainage," Sch. Sci. Math., 1908, pp. 129-139.

River at Kenosha furnishes an admirable example of this process. This stream, entering the ancient lacustrine plain about five miles north of Kenosha, bends directly south and flows in a broad, somewhat winding valley almost to Kenosha before entering the lake. It is clear that any recession of the lake cliff must inevitably lead to the interception of the Pike River valley where its curves approach the lake, with a consequent shortening of the stream itself. Such interception actually has occurred twice. A part of the harbor at Kenosha is a curved lagoon situated in a rather narrow valley, open at both ends to the lake, and directly south of Pike River and within its projected course. This lagoon is clearly a severed part of the Pike River valley, and was recognized as such as early as 1847 by Lapham.[11] Previous to 1924 the mouth of Pike River was in the NE¼ of Sec. 30, T. 2 N., R. 23 E. In 1924 or 1925 a breach was opened by wave action at a curve in the valley one-half mile farther north. For a time the river possessed two outlets, and these even alternated as first one and then the other was closed by wave deposition. At present, however, the former mouth seems to have been permanently closed by the building of the beach ridge, and the old channel lying south of the present river mouth has become a stagnant lagoon.

At many places in the Great Lakes region the conditions have been favorable for intercision. The combination of winding stream valleys parallel to the lake shore and rapid shore recession has resulted in intercision during both ancient and present lake stages. Intercision at one of the higher lake stages has occurred just north of Waukegan,[12] Illinois, and also in northern Ozaukee County, Wisconsin.[13] Intercision is impending in the present course of Sucker Creek, Ozaukee County, Wisconsin, and at another curve in the Pike River valley one-half mile north of its present mouth. In the instance first mentioned, the authors in March, 1929, measured the distance across the upland between the top of the lake cliff and the top of the cut bank in the river valley and found it to be twelve feet, one inch. The distance between the two water bodies at lake level, however, is much greater on account of the slump both in the lake cliff and in the valley wall. Probable cases of in-

[11] Lapham, I. A., "On the Existence of Certain Lacustrine Deposits in the Vicinity of the Great Lakes," Am. Jour. Sci., 2nd Ser., Vol. III, 1847, pp. 90-94.

[12] Atwood, W. W. and Goldthwait, J. W., "Physical Geography of the Evanston-Waukegan Region," Ill. Geol. Surv. Bull. 7, 1908, pp. 83-84.

[13] Goldthwait, J. W., "Intercision, a Peculiar Kind of Modification of Drainage," Sch. Sci. Math., reprint, 1908, p. 2.

tercision may be seen on maps of the Mentor, Ohio, Quadrangle, and also the Cleveland, Ohio, Quadrangle. In the case of the latter, Whittlesey's map on page 26 of his report on the "Freshwater Glacial Drift of the Northwestern States" (cited above) strengthens the suggestion of intercision exceedingly.

Two conclusions may be drawn from this study of shore recession: first, the recession is rapid and wasteful where it is not checked by breakwaters or "groins," or by a temporary beach of the lake's own making; and, second, the rate of recession is not uniform but variable, being surprisingly rapid at times of high lake level, and very slow at times when the lake waters are low.

THE TILDEN METEORITES

A. R. CROOK
State Museum, Springfield
and
O. C. FARRINGTON
Field Museum, Chicago

The only meteorites thus far found in Illinois are three which fell at Tilden, forty-five miles southeast of St. Louis, about one o'clock in the afternoon of July 13, 1927. Portions of this fall are now in the Illinois State Museum, the Field Museum of Natural History, the United States National Museum, and the Museum of Iowa State University. For thirty-five years the authors have been watching for meteorites in Illinois and are pleased to be able finally to report this fall.

Eye witnesses and men[1] who picked up the aerolites furnished many of the facts. C. C. Wylie,[2] Professor of Astronomy at Iowa State University, visited the locality shortly after the fall and reported that the meteor came from the southeast and at an angle of about fifty degrees from the horizontal. He regarded the velocity of the meteor in the upper atmosphere as being as much as thirty miles per second. While high in the air, it exploded three times, with such force as to cause windows to rattle and dishes to shake. Many people reported a hum and thought an airplane was passing and backfiring.

From the fall, three separate masses were obtained. These, referred to hereafter in this paper as Nos. 1, 2, and 3, weighed nine, forty-six, and one hundred ten pounds, respectively. A map of the region (Fig. 1) shows the locations where the three pieces struck.

The distribution of the individuals in falling followed an order which has been observed in other cases and to which attention was first called by Farrington, viz: that the heavier individuals, on account of their greater momentum, go farther along the course of the meteor than the lighter ones. The time intervals between the explosions and the fall of each stone were reported by

[1] Postmaster Robert Murphy, Henry Dunn, Lindsay Mansker, and Allen Raney.
[2] Science, November 11, 1927, page 451.

Wylie (loc. cit.) to be: For the largest stone (No. 3) "a few seconds after the blasts," for the forty-six pound piece (No. 2) "perhaps three minutes after," and for the nine pound piece (No. 1) "three to five minutes or five to eight minutes after." These intervals, of course, cannot be fully interpreted unless the positions of the observers with relation to the points of fall are shown. If the estimates were made by observers at the points of fall, they might be of equal value, but if distant from the points of fall, for example, an observer at the point of fall of Mass No. 3, reporting the time of fall of Mass No. 1, allowance must be made for the

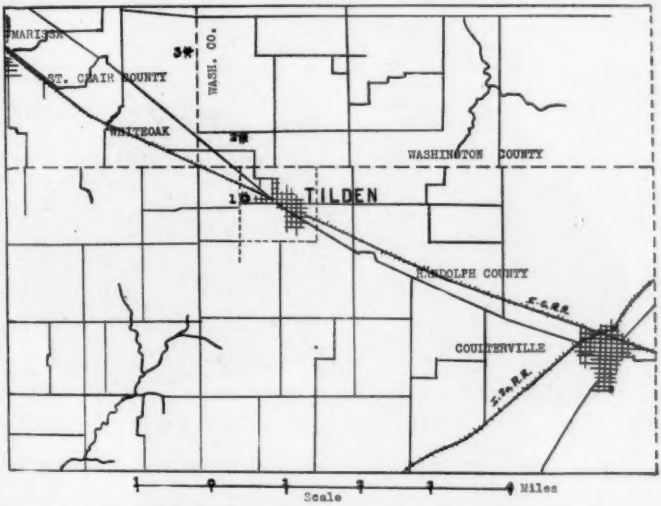

FIG. 1. Map of the vicinity of Tilden, Illinois, where three fragments of meteorites fell, each in a different county.

time required for the sound to travel over the intervening distance. That the fall of any of the masses could have been delayed from "five to eight minutes" after the explosions, however, seems improbable. It is to be regretted that no record of the time interval between the several explosions seems to have been made. Otherwise, this fall is unusually well reported, since it occurred in the day-time and attracted the attention of people generally.

Mass No. 1 fell on the west boundary line of the town of Tilden, fifty yards north of the street that divides the village into equal parts. No. 2 traveled three-quarters of a mile farther, directly north, and landed on the Dunn farm in a field of clover.

No. 3 fell two miles northwest of No. 1 on the Mansker farm in a field of cow peas. Though all of these masses came to earth within a circle having a radius of one mile, yet they fell in three different counties, Randolph, Washington, and St. Clair.

Mass No. 1 was found by a miner, Raney, who was cutting grass. He heard the explosion and shortly afterwards saw something strike the ground about two hundred feet away in a neighboring lot. He went to the spot at once and soon noticed a hole, nine inches deep, in which was an irregularly shaped, black, lustrous stone measuring four and one-half by six and one-half by seven inches and weighing nine pounds. This is the smaller individual shown in Fig. 2.

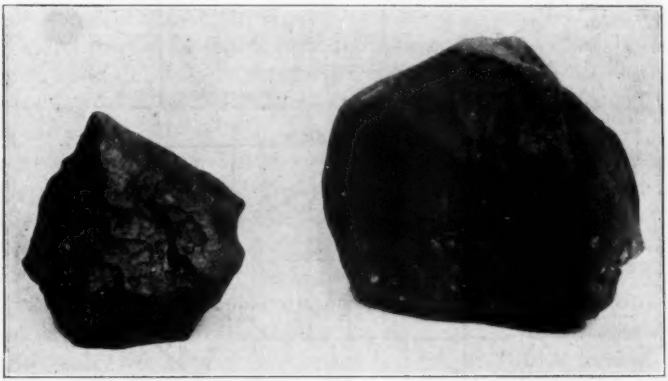

FIG. 2. Tilden meteorites. The one at the left weighed 9 pounds, and the one at the right 46 pounds.

Mass No. 2 was first observed by five men on the Dunn farm who were starting to plow after dinner. They heard explosions and a "swish." They looked in time to see faint smoke, then dust thrown up in a field at a spot seven hundred feet away. They said "they were afraid," but after a few minutes went to the place, and Harry Hirte dug up the No. 2 piece. (Fig. 3.) It had penetrated the stiff clay for seventeen inches, punching a hole much as a shell fired from a cannon does in the side of a battle-ship. This stone measures seven and one-half by eight and one-fourth by ten inches and weighs forty-six pounds. It is the larger stone shown in Fig. 2.

Masses Nos. 1 and 2 are now in the Illinois State Museum, with the exception of sections sawed from No. 2 for the Field and

National Museums and with the exception of fragments which souvenir hunters had removed previous to its acquisition by one of the authors.

Mass No. 3, secured by Wylie and now at the University of Iowa, attracted the attention of members of the Mansker family because of a sound which they interpreted as an airplane crashing to earth behind their barn, beyond a narrow wood-lot. At the end

FIG. 3. The 46-pound meteorite dug up by Harry Hirte.

of a two-day search, in which several persons joined, Mansker found a hole in which the stone was tightly wedged. Using pick, shovel, and crow-bar, after considerable labor, he extricated the mass. It has penetrated the hard, yellow clay soil to a depth of forty-eight inches. It is similar in general appearance to No. 2, the forty-six pound piece. Its weight was two and two-fifths times greater than that of No. 2 and, curiously enough, it penetrated the soil to a depth two and two-fifths times as great as No. 2 did.

All the different masses found were reported by the finders to be *cold* when first touched.

The faces of the masses found do not fit together. This might indicate that connecting pieces were lost. However, all have the same appearance and constitution. A dark, lustrous glaze, "meteoric varnish," covers them entirely.

The nine pound piece has five sides triangular in shape, and four with four or five edges. The upper corner in the photograph (Fig. 2) appears to have been the nose or front side in falling, since there is a slight indication that the fused crust flowed back from this sharp corner. The pits on the sides are also somewhat elongated parallel to this direction.

The forty-six pound individual has ten, fairly well defined, relatively plane surfaces, exclusive of the two edges from which the original crust was broken by souvenir hunters before the specimen was secured by the Illinois State Museum. One would conclude that in falling the mass might have shifted about, since all planes seem to have experienced about the same amount of friction and to have been nearly equally fused. Neither from the shape of this mass nor from the appearance of the crust can positive evidence of its orientation in falling be determined. However, the largest plane surface, approximately eight by nine inches square, may have been the rear or lee side, since from this base the other surfaces converge toward an apex. The total height of the stone above this base is eight and one-fourth inches. All the surfaces are somewhat pitted, though not abundantly, and least of all the broad side just mentioned. This is what would be expected if it were the lee side.

The pits on all the surfaces are sub-circular to elliptical in form. They may be single or confluent. The diameter of the sub-circular pits is less than one inch and few of the elliptical ones have a greater diameter than this.

The crust is everywhere black in color, dull in luster, and rough from the inclusion of metallic grains whose slight protrusion shows that they were less fusible than the siliceous ingredients.

The interior of the specimen is light ash-gray in color and abundantly sprinkled with small metallic grains. There are also many subcircular spots of a darker gray which indicate the presence of chondri. Apparently some rusting of the metallic grains took place preterrestrially, as brown spots of this rust dot freshly broken surfaces of the interior.

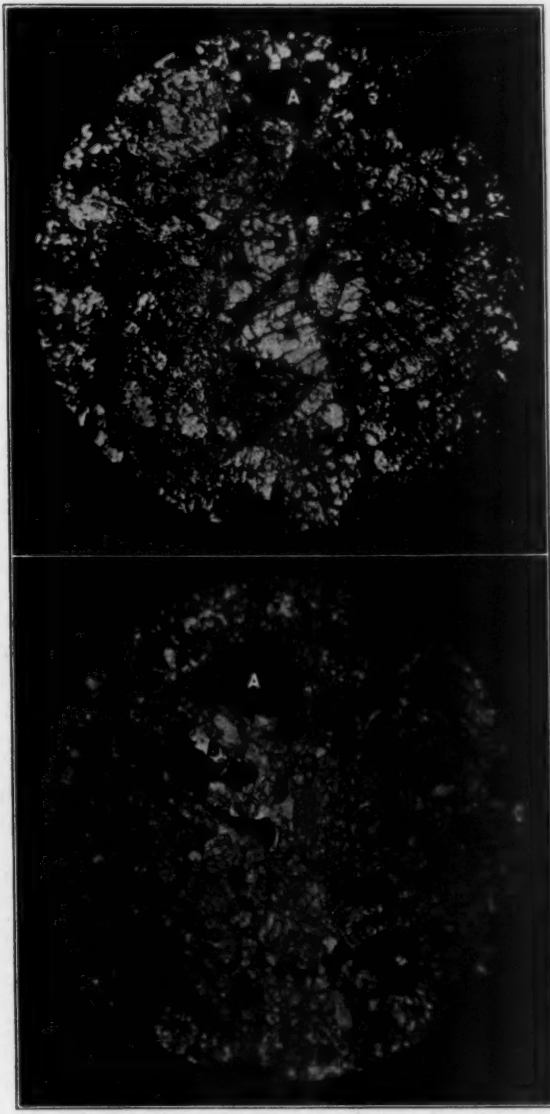

FIG. 4. Photomicrographs. (*Courtesy U. S. National Museum.*)

Above, light polarized and nicols crossed. *Below*, another portion in ordinary light.
A=iron; B=oligoclase; C=olivine; enstatite at right of C.

The substance of the meteorite is only fairly coherent. It can be readily cut with a hack-saw and does not take a polish. This rather friable character, light color, and small number of chondri, class it with the small group designated by Brezina as white chondrites. The substance of the meteorite resembles closely that of Drake Creek, but differs from it in not being veined. The specific gravity of the stone, determined on a fragment from the interior weighing eleven grams, is 3.49.

Under the microscope the outlines of the chondri, which are visible to the naked eye on a plane surface, largely disappear, and the field in ordinary light is seen to be a granular aggregate of transparent, colorless, highly fissured minerals, among which opaque metallic grains are thickly disposed. In ordinary light there is nothing to distinguish the transparent minerals one from the other, nor are the chondri separated to the eye from the associated minerals. In polarized light, high interference colors and a relatively large size of grains indicate the presence of olivine, while a smaller size of grain and lower colors distinguish enstatite. Neither feldspar nor glass, which usually accompany the pyroxenes of the chondritic meteorites, could be distinguished in the sections examined. Distinct crystal outlines are lacking in both the olivine and enstatite grains. Some of those of olivine have rounded forms and, being single individuals, are probably to be regarded as monosomatic chondri of that mineral. A few barred forms are seen, and these are more definitely of a chondritic form. The largest monosomatic olivine chondri are from 0.5 to 0.8 mm. in diameter. All other individual forms are smaller. The eccentric radiating enstatite chondri so characteristic of many chondritic meteorites have not been noted in any of the sections examined.

The metallic grains of the meteorite are of exceedingly irregular forms, branching and spreading in all directions. The longest one noted was only two millimeters in length, and from this size they diminish to mere dust.

The crust of the meteorite measures 0.5 mm. in thickness. The zones of fusion, absorption, and impregnation in the crust are plainly marked. As would be expected in a meteorite so porous as this, the impregnation zone is much the widest, an average width being 0.4 mm., while the absorption zone averages 0.1 mm. and the fusion zone 0.05 mm.

Dr. R. S. Bassler, Head Curator of Geology at the United States National Museum, furnished photomicrographs (Fig. 4) from sections of the piece sent that institution.

A quantitative chemical analysis of a portion of the forty-six pound mass was made by H. W. Nichols, Associate Curator of Geology, Field Museum of Natural History. This gave the following percentages:

SiO_2	41.22
Al_2O_3	3.69
FeO	22.28
NiO	0.99
CoO	0.04
CaO	0.91
MgO	22.30
Na_2O	0.53
K_2O	0.00
Fe	6.38
Ni	0.31
Co	0.02
S	2.31
P	0.15
H_2O	0.03
	101.16
O=S+P	1.38
	99.78

CAUSE AND PREVENTION OF POTENTIAL ROCK-FALLS NORTH OF SAVANNA, ILLINOIS*

GEORGE E. EKBLAW
Illinois State Geological Survey, Uurbana.

An unusually interesting problem in engineering geology is involved in a situation that occurs two miles north of Savanna, in the northwest part of Illinois. At this locality Mississippi River flows almost against the east wall of its valley (fig. 1). The valley-wall itself is a precipitous bluff approximately 250 feet high. A

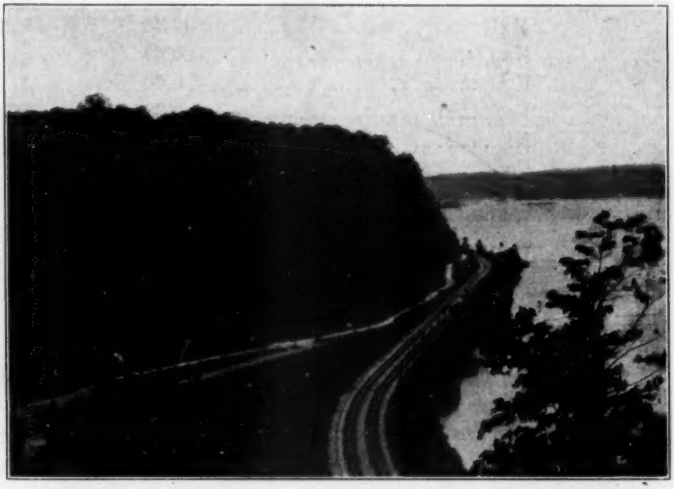

FIG. 1. View of bluff two miles north of Savanna, showing relations of the river, the railroad, and the highway. (*Photo by Illinois State Highway Division.*)

public highway follows the foot of the bluff, and the main northwest line of the Chicago, Burlington, and Quincy railroad follows the bank of the river near the bluff.

At the precise locality under discussion (fig. 2) the highway originally lay between the railroad and the river, but some years ago the railroad company realigned its roadway and prepared a new public road between the railroad and a projecting nose of the bluff. In order to make room for the new public road it was

* Published with permission of the Chief, Illinois State Geological Survey.

necessary to remove the toe of the talus slope at the foot of the bluff. This caused the talus to slide down from time to time, so that for about two years the railroad company had a steam shovel on hand to keep the road clear. A wider roadway with more clearance at this place was desired for the new concrete highway (State Highway No. 80) that is being constructed along the river, so the rest of the talus slope was removed (fig. 2) and was dumped into the river on the west side of the railroad. Preparations were made to blast down an intermediate shelf of rock along the south part of the nose.

FIG. 2. Near view of bluff two miles north of Savanna, where conditions favor rock-falls. (*Photo by O. F. Goeke.*)

While this work was in progress, some small rock-falls occurred at the north part of the nose, where the talus had been completely removed (fig. 3). These falls alarmed the resident highway engineer, who informed the district engineer, who in turn appealed to the Illinois State Geological Survey for advice. Accordingly an examination was made, about a year ago.

This examination revealed that most of the rock exposed in the bluff consists of Silurian limestone and dolomite (fig. 4), of which the upper part belongs in the Niagaran series and the lower 30-40 feet belongs in the Alexandrian series. About 10 feet of Maquoketa (Ordovician) shale was exposed beneath the limestone at the base of the bluff where the talus had been removed. Seeps and springs occur at and just above the contact between the shale and limestone. The limestone is covered by a mantle of loess as

much as 40 feet thick, approximately. Sinkholes occur on top of the bluff and extend through the loess into the limestone.

The rainfall that is precipitated on the top of the bluff soaks down through the loess and gathers in the sinkholes, whence it continues its way downward through solution channels and crevices in the limestone until it encounters the relatively impervious shale.

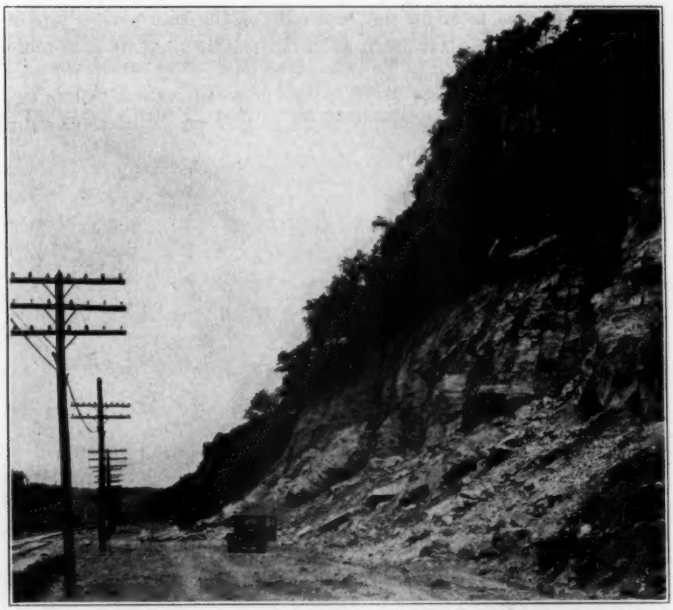

FIG. 3. Close view of the same bluff, showing rock exposed by clearing away talus and also showing small rock-falls. (*Photo by Illinois State Highway Division.*)

Thence it moves laterally along the top of the shale to issue as seeps or springs wherever the contact between the shale and the limestone may be exposed. This water tends to soften the shale and to lubricate its contact with the limestone. When the shale is softened it tends to yield under the weight of the overlying rock. The removal of the talus allows the shale to squeeze outward, which in turn allows a mass of the limestone along the face to settle, to break loose, and to fall towards the road. In small rock-falls (fig. 5) there would be a rotatory movement outward at the base and downward along the fracture plane, but in large falls the top of the

rock would gain momentum more rapidly than the base and would topple outward soon after the movement started.

In view of these conditions it was recommended that such small falls as had already occurred should not be removed, but that they should be supplemented by other masses of rock, either blasted from the face or recovered from the dump. These masses would serve as an artificial talus (fig. 3) that would prevent the shale from yielding laterally and thus would prevent rockfalls. The insertion of well-points along the contact between the shale and limestone in order to drain away the seepage before it emerged and the sealing of the surface sink-holes were also considered, but they were not deemed to be feasible or wholly effective schemes.

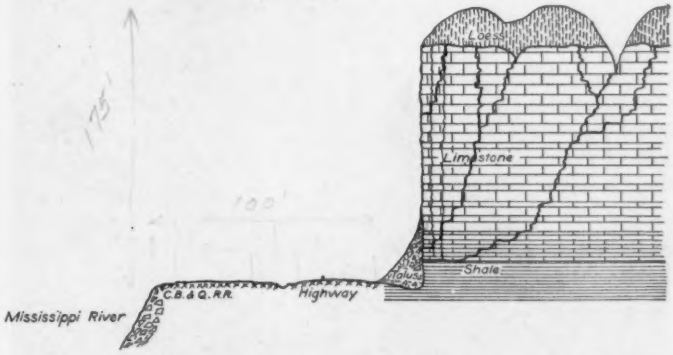

FIG. 4. Diagrammatic cross-section sketch showing geological conditions at highway cut two miles north of Savanna.

An interesting complication in the situation arose shortly after the examination was made. Rain was falling during the day of the examination and continued during the following night. About two o'clock of the next afternoon a large mass of the rock-shelf at the south end of the bluff fell across the road and railroad. The contractor's engineer, who was present at the time, reported that the whole mass moved bodily outward a few feet, settled downward, and then the upper part fell forward. Fortunately, the two rigs that were drilling holes for blasting were sitting one on either side of the mass that fell, but one of them was almost marooned and it was hurriedly withdrawn to safety. More fortunately, it caused no disaster on the railroad, although the fall occurred just in time to block the fastest passenger train on the railroad, the Oriental Limited, for two hours, and the super-

intendent of the railroad was on the train! As a result of the fall and its consequences, another conference was held at which not only the district engineers but also the state highway engineers and the acting chief engineer of the railroad company were present. The situation was reviewed and the recommendations repeated. The engineers concurred in the recommendations and the artificial talus was prepared as soon as practicable. Since then no rock-falls have been reported.

FIG. 5. Close view of small rock-falls and talus at foot of bluff. (*Photo by Illinois State Highway Division.*)

This situation aptly exemplifies the intimate relation between geology and engineering. It shows how important it is for engineers to know and to appreciate ordinary geological relations. It also shows what disastrous results may follow ignorance or neglect of these relations, and what simple measures may be adopted to prevent such avoidable consequences.

THE BUILDING OF A DAM

FRED R. JELLIFF
Daily Register-Mail, Galesburg.

March 13, 1928, St. Francis dam, a year old, spanning Santa Clara valley, California, and behind which was a large reservoir, constituting part of the water supply of Los Angeles, gave way, and the contents swept on to the ocean, destroying cities and causing the death of three hundred people and damages estimated at $15,000,000. Investigations were started and eminent geologists and civil engineers were summoned to examine the site and its formations and rumors of earthquake and fault disturbances, to ascertain if possible the cause of the catastrophe. Early reports indicated that one end of the dam was anchored in shale, susceptible to aqueous action, and the other in a conglomerate. On March 28th, the commission appointed by the governor, found that the dam had a defective foundation. Los Angeles recognized its responsibility in the premises and honorably prepared to meet the bill for damages. It seems that a more thorough examination by expert geologists before the dam was built might have revealed the unsuitability of the shale, and resulted in a different type of construction or the selection of a different site.

In the same year floods destroyed dams in New England, while southern Atlantic seaboard states were in dread lest sundry large dams that were put to a severe strain would collapse.

ILLINOIS EXPERIENCE

To this time dams built in our section of Illinois have not been permanent, as is shown by the experience in the vicinity of Galesburg where there are six reservoirs, the largest of which is Lake Bracken built by the Chicago, Burlington, and Quincy railroad company five years ago. The dams of four of these have at various times been swept away. In June, 1924, there were exceptionally heavy rainfalls, which resulted in the destruction of three dams that subsequently were rebuilt. On September 1, 1926, an unusually heavy rain flooded the Lake Bracken reservoir, tearing up the rip-rap of the spillway and the clays and shales underneath and causing the company a $50,000 expense in concreting the spillway.

When therefore the Atchison, Topeka, and Santa Fe railroad company started last summer to construct a dam over the south fork of Henderson Creek in the north half of sections 32 and 33, Henderson township, northwest of Galesburg, it occurred to us that it would be worth while to note what the preliminary work would be, how extensive would be the effort to ascertain the nature of the formations on which the dam must rest, and what steps would be taken to make the dam secure and permanent. It was learned that the surveys and plans were prepared under the direction of H. W. Wagner, chief engineer of the company, at Topeka, Kas., and that the contract had been let to the Cook-O'Brien construction company.

TOPOGRAPHY OF THE REGION

The south fork of Henderson Creek originates at an elevation of 806 feet four miles east of the dam and runs due west. The elevation of the creek at the dam site is 715 feet, so that there is a fall of 91 feet when the dam site is reached. The longer watershed lies to the south of the creek and approximates a mile in width, while that at the north is about half a mile in width. The four longer streams come in from the south, and the shorter from the north. Those from the south descend from an elevation varying from 800 to 789 feet, and those from the north descend from elevations ranging from 800 to 771. There are, in addition, on each side a number of small ravines that reach the creek bottom. As the dam is approached the depth of these tributary valleys and ravines increases until the stream that descends on the south side nearest the end of the dam has a fall (from the watershed) of approximately seventy feet. The topography for two miles above the dam is therefore rough, and the nearer the dam is approached, the more broken it becomes. The steepness of the descent over much of the area means that in case of heavy rains, the volume of the stream is rapidly increased.

The stream near its source is in a very shallow channel at the 806 level, and its bed is composed of soil and subsoil. In the Lincoln park area and east of it there are rounding hills, and after entering the park the stream cuts more deeply, exposing the subsoil and yellow clays. West of the park the creek runs most of the way to the dam on the south side of the valley, and the bluffs display glacial deposits and, farther west, Coal Measure formations, as is proved by the coal vein exposure at the dam site. There is a constriction of the valley as the dam site is neared. The more

westerly ravines on the north side show glacial drift and Coal Measure shales, while the existence of the shales and coal below the bottom land is disclosed by the existence of the debris of a coal mine and the well logs made by the company.

PROBLEMS OF CONSTRUCTION

In this Coal Measure valley, with but little actual rock formation for anchorage, the problem of the Santa Fe was to avoid flood damage, to guard the dam as much as possible from leakage or from penetration by burrowing animals, and the shale formations from water in old coal mines, to make sure that these mines did not pass under the dam, and to satisfy itself that there was available a sufficient quantity of impermeable glacial clay for the up-stream side of the dam.

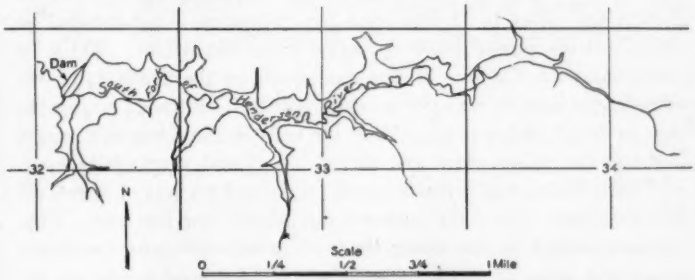

FIG. 1. Sketch map of Santa Fé reservoir northwest of Galesburg.

To ascertain the surface conditions, the engineers went over every foot of the ground to be covered by the reservoir, with a length of a mile and a half and an average width of seven hundred feet, with a drainage district of 7.7 miles, a flood area of approximately 150 acres, and with a capacity of 600,000,000 gallons. They charted every peculiarity of the surface, every sink caused by a coal mine—for the region had been mined extensively—every spring, the lines along which the sheet water appeared, and every soggy place, and took a multitude of levels. For example, all along the north side of the valley sheet water was escaping at a level five to six feet above the valley floor. One quarter of a mile east of the site of the dam, they found the slack of an old mine operated on the bottom itself, and from which a bitter spring was issuing, while on the south side of the valley still farther east they discovered a copious spring the water of which was excellent.

Again, along a ravine a few rods east of the east end of the proposed spillway they located old coal mine workings, and just above the creek level and included in the dam site they discovered a seam of coal exposed with a layer of niggerheads not far above, the only really hard rock encountered.

BORINGS

As a further precaution, the company caused the sinking of seven borings across the valley along the line of the dam, three across the dam site along the line of the supply pipe and four along the direction that the spillway was to take. Logs were kept of all these borings, and notes were made on the nature of all materials penerated, the levels at which water appeared and in what quantity, and the nature of the formations on which the footings of the concrete core were to rest. The borings varied in depth from 34 feet in the valley to 77 feet from the hill summits but reached at their bottoms substantially the same shale formations. Three of the borings in the line of the dam were on the north hill, two were in the bottom, and two on the south hill. Without giving the logs in detail, suffice it to say that the ones on the north hill passed through the yellow clays and drifts, bluish and gray shales, coal, and dark shales, and revealed several veins and pockets of water, all of which were below the proposed foundation for the core. This water appeared to run along the surface of the more resistant shales and make its way to lower levels. The deepest boring on the south hill showed a deeper layer of drift, then shales, and next an abandoned coal mine, the seam of which was displayed in the creek bank. The north hill side, starting from its summit, was covered with soil, which increased in depth to the valley. The borings in the bottom showed alluvium to the depth of eight to ten feet and, under this, blue and brown shales that were judged hard and durable enough to serve as the foundation of the concrete core across the bottom.

As to the character of the material at the sides of the spillway, a general section, kindly furnished me by Dr. George E. Ekblaw of the State Geological Survey, shows soil, subsoil, silty clay, slightly calcareous silty clay, sandy dense clay, gravel, sand, and finally brown, blue, and mottled and calcareous tills, altogether representing a thickness of thirty feet, with some bowlders of coal and numerous igneous and metamorphic rocks. The till comprises eighteen feet of the section and is of Illinois age.

Having these data on the formation derived from a study of the logs, the engineers felt that the dam to be permanent must be securely anchored, that it must be safeguarded against water seeping through and undermining it, that the abandoned coal mine rooms must be sealed up, and that the reservoir side of the dam must be made as impermeable as possible.

CONCRETE CORE

The main trouble was met in the construction of the fortified concrete core for the dam clear across the valley, a distance of 860 feet. Over most of the bottom this wall, two feet in thickness at the base and one at the top, and fifty-three feet high, extends thirteen feet below the surface of the bottom, and for 330 feet it rests on brown and blue shales. From this central portion, the trench for the bottom of the core extends by a series of steps upward. There are thirteen of these treads, so to speak, on the

FIG. 2. Lengthwise section of dam, showing step-construction core.

1. Top of dam; elevation, 762 feet.
2. Top concrete core, elevation, 757 feet.
3. Concrete core; length, 860 feet.
4. Ground line; elevation, in bottom, 715 feet.
5. Bottom of core; elevation, central part, 703.2 feet.
6. Stream channel.
7. Spillway; elevation at weir, 752 feet; width at weir, 190 feet.

north side. The lowest two rest on tough, brown shale, the next two on a crumbly brown clay, and the rest evidently on drift and yellow clay, until the last section is reached, which is fourteen feet in height and 160 feet long and is tied into the concrete spillway, and rests on yellow clay. In the south hill the footings of the concrete core rest on shale for seventy feet and on glacial deposits the rest of the way up. The core is anchored in the north hill a distance of 340 feet and in the south hill a distance of 180 feet, with the creek running close to this south bluff.

The dam itself overtops the core five feet, having an elevation of 762. It is 18 feet wide at the top and 256 at the base. The dam is therefore built against this concrete core. From the core

the base of the dam extends 134 feet on the reservoir side, with a slope of three to one, and 122 feet on the downstream side, with a slope of two to one. The top of the dam is 45 to 47 feet above the varying ground line of the creek bottom and 51 feet above the pipe line, which extends under the dam. It required 132,000 cubic yards of material to make the dam. On each side of the concrete core there is a layer of puddled clay fifteen feet in thickness at the base and tapering to seven feet at the top. The upstream side of the dam is composed of comparatively impervious glacial clay with a coating of six inches of gravel and twelve inches of hard rock rip- rap. In preparing the ground for the dam, the soil in the bottom was removed to the depth of a foot and the alluvium underneath was then ploughed deeply in paralleled ridges so as to give it a corrugated appearance and then the tough clay of the superstructure was dovetailed into this.

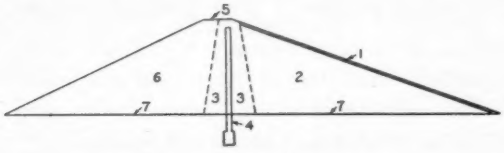

FIG. 3. Cross-section of dam.

1. Reservoir side of dam, paved with six inches of sand and one foot of riprap.
2. Impervious material.
3. Puddled clay core, 15 feet thick at base, narrowing at top.
4. Concrete core, 2 feet thick at base; remainder one foot thick.
5. Top of dam, 18 feet across.
6. Down-stream side of dam, less impervious material.
7. Base of dam, 256 feet across; 134 reservoir side, 122 down-stream side.

Elevations: top of dam, 762 feet; bottom, 715 feet; top of core wall, 757 feet; bottom of core wall, 703.2 feet; normal water level, 752 feet.
Slope: reservoir side, three to one; down-stream side, two to one.

Borings along the line of the 24-inch supply pipe, which extends under the dam, show soil, sand, gravel, and clay before the shales are reached on which the core at this point rests.

TROUBLE WITH WATER

The characteristic feature of this dam is the concrete core. In the construction of this core there was little trouble until the trenching from the north end reached a point about three hundred feet north of the creek, and then a great volume of water gushed up. The logs especially on the north side had shown water at higher levels and also a common water level at the 700 elevation, and it looked as if the water, disseminated throughout the forma-

tions and seeking this lower level, had found an outlet at the 712 level when the trench reached that level. Two pumps were set to work and for several months were kept busy, until the concrete wall could be built, extending below this influx stream and cutting it off.

The digging of the trench on the south side was attended with great difficulty. The greatest depth attained was 36 feet, and it was near the bottom at this depth that the old coal mine was struck, with five penetrable rooms in which the props were still standing. Much of this distance was in drift, but the coal mine was some eight feet below this, with niggerheads and a dense blue shale above the coal. The sealing off of these rooms before building the concrete core was no slight task, and extensive propping had to be done. There is still some apprehension, judging from the sink holes, that the mine workings may honeycomb the entire hill, and perhaps cause trouble in the future.

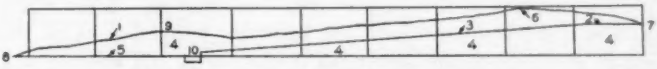

FIG. 4. Profile, north side of spillway.

Scale approximately natural. Vertical lines 100 feet apart.
Length of spillway, 930 feet. Total descent of spillway, 40 feet; elevation at weir, 752 feet; height of weir, 2 feet.

1. Ground line of hill.
2. Floor of spillway, horizontal.
3. Floor of spillway, descent.
4. Flacial clay.
5. Floor of spillway, after leaving well.
6–9. Elevations: 6, 768 feet; 7, 750 feet; 8, 710 feet; 9, 732.7 feet.
10. Spillway well.

IMPORTANCE OF SPILLWAY

The construction of the spillway on the 750 contour line on the north side of the dam from the summit of the hill was most carefully planned, the engineers realizing that a poorly built and inadequate spillway is a chief source of danger from flood. The per cent of failures from this source is put as high as ninety. The structure is 930 feet long, extending from the contour mentioned to a few rods from the creek. The upper end flares out to a width of 310 feet and a width of 190 feet at the weir, the elevation of which is 752 feet at its crest, the normal water level. The east end of the spillway is level for 100 feet, and from the weir there is a fall of 50 feet to the end of the spillway. The excavation through the hill is deepest, about 24 feet, at the center of the east hill, and about 20 feet, at the center of the west elevation.

From the weir the spillway tapers to a width of 120 feet and then gradually narrows to 50 feet, from which extend the fish tails, which are 88 feet long and 210 feet across at their far end.

It was when the excavation of this spillway was well along that Dr. Ekblaw made his visit and saw the superficial and drift clays exposed, the excavation the entire length of the spillway being in this material, until the alluvium deposits of the bottom were reached. His observations do not appear to differ materially from the logs, save that the logs do not differentiate the clays closely. The engineers tell us that the check-up on the logs during the progress of the work shows that the logs are approximately accurate, and this was our own observation.

It was estimated that 92,000 cubic yards of material were contained in the spillway, and this was largely available for dam construction. Borings going below the glacial clay on the spillway site penerated the Coal Measure formations, and the boring at the crest of the hill disclosed 40 feet of surface materials and clays.

The building of the spillway is still in progress. A tile drain was laid along the north side and below the bottom, to catch the seepage from the higher elevations to the north, and another was laid under the surface of the spillway. The floor of the structure is of fortified concrete nine inches in thickness to the 716 level, where there is a fall of seven feet to a paving two feet in thickness, whence the water flows over the concreted fish tails area to the bottom adjacent to the creek. The sloping sides of the spillway are also protected by a wall of fortified concrete seven feet high and nine inches in thickness.

SAFEGUARDS AGAINST FLOODS

To prevent any possibility of a flood forcing the water over the top of the dam, its top is built ten feet higher than the normal water level, at elevation of 752. The curved weir at the upper end of the spillway is two feet in height. The spillway is ample to carry four feet of water above the weir. To go over the top of the dam the water would have to rise six feet higher.

The engineers believe that they have a dam that can stand the test. They have realized the dangers. It is true that the shales, brought up on the south side of the dam during the core trenching, soon disintegrated when exposed to the rains, because of their lime and possibly sulfur contents, disclosing that such

shales have their weak points, but the belief is that the concrete core and the substantial and close construction of the dam will safeguard this material against exposure. It is admitted that there may be some slight seepage through even the concrete, and that the usual swampy place may be found on the down-stream side.

A recent statement in the Decatur Herald says that the concrete apron of the comparatively new dam at Decatur had sprung a leak and that plans were being made to stop it. While the lake Bracken dam south of Galesburg has to date resisted the floods that have assailed it, yet shortly after it was built it developed at its east end a serious leak, which is causing the loss of 500,000 gallons of water daily, and what produces this leak is not yet determined, although the company has spent a large sum in trying to close it.

One cannot see why there should be any considerable seepage through the Santa Fe dam with its concrete core, its hard packed, puddled clay covering, and its glacial clay front, with rip-rap imbedded in gravel.

It must be remembered that the collapse of even a small dam may be a costly thing for a corporation, and that it is likely to cause large damage. We believe that the Santa Fe has exercised great scientific care in the construction of this dam to safeguard it at every point.

NEED OF GEOLOGICAL DATA

All this leads to the conclusion that before the construction of a dam there should first be procured just such topographical and geological information as that obtained by the Santa Fe, and that it would be best for a careful investigation of the site and area to be made early, under the direction of the State Geological Survey, that there may be acquired accurate information regarding the formations and their adaptability for such a structure. It is believed that if this were done and the Survey were kept informed of developments as the work progressed, and its advice sought, dangers arising from underground causes would be largely reduced. This is of especial importance now that reservoirs are multiplying, since both cities and corporations are seeking them more and more as sources of water supply.

All the indications are that when the dam is completed and the reservoir is full it will constitute an addition to the beautiful scenery in the vicinity of Galesburg.

CUSPS ON THE BEACH OF LAKE MICHIGAN AT EVANSTON, ILLINOIS

C. E. NEEDHAM
Northwestern University, Evanston.

The cusps on the Evanston beach, in common with those described from the sea shore, are irregular heaps of sand, gravel, and boulders, occurring rather uniformly spaced, trending at right angles to the water's margin, and tapering to a point near the water's edge. They should not be confused with the much larger and more permanent cuspate forms found on the prograded shore near Kenosha, Wisconsin. They bear no particular relation to the latter, except that both are formed by wave action.

MATERIALS OF THE SHORE AT EVANSTON

With the exception of a few small areas near Milwaukee and Racine, Wisconsin, no bed rock exposures occur along the lake shore in the vicinity of Evanston. The lake is everywhere bordered by bluffs composed entirely of glacial till and lake deposits. The till is commonly bouldery and is easily eroded by the waves. The clay particles are carried some distance off shore and deposited, but the sand and gravel make up an abundance of beach material which is easily transported and reworked by the waves.

FORM

The cusps on the Evanston beach, when best formed, have the shape of a rude isosceles triangle with the base parallel to the shore line and the apex pointing toward the water. However, they are often imperfectly formed, and some are merely rude piles of gravel or sand with no characteristic form whatsoever. Some are sharply pointed, while others are very blunt at the apex. Some have their greatest dimension from apex to base, while others are longest parallel to the base. It appears that as a general rule the smaller cusps are more slender and more nearly ideal in shape than the larger ones.

SIZE

Much variation in size is found in the cusps, but in any particular set the variation between individual cusps is slight. The largest cusps observed were found to have a length of about 12 feet from apex to base, a width of about 20 feet across the base, and a height of about 18 inches above the general level of the beach. The smallest cusps measured about 18 or 20 inches in length and width and one or two inches in height. Smaller cusps are, no doubt, frequently formed, but because of their slight relief and ease of destruction they escape detection.

In some cases the cusps form a part of the beach ridge thrown up by storm waves, in which case the base of one cusp merges into the base of its neighbor. When the beach ridge is lacking, as it often is, the intercusp areas are likely to run entirely through the line of cusps as a shallow trough.

MATERIAL

In building the cusps, the waves make use of any material available. Since the size of the cusp depends on the size of the waves, and since the larger waves move coarser material than the smaller ones, it follows that as a general rule the larger cusps are made of pebbles from one-half inch to three inches in diameter, and the smaller cusps are made of sand and gravel ranging in size from wheat grains to corn grain. This is largely brought about, no doubt, by the fact that much coarse material is nearly always available for the strong waves to move, and it does not follow that large cusps could not be made of fine sand. But if a difference in the size of material does exist, it is always true that the cusps will be made of coarser material than the intercusp areas.

SPACING

The distances between the apices in a set of cusps are remarkably uniform. In the largest set measured this was found to have an average value of 22 feet; in the smallest set, about 6 feet. While the distances in every set depart from the average (in the largest cusps as much as 5 or 6 feet), the uniformity is remarkably striking. The spacing of one set of eleven cusps will illustrate the point. The distances in feet are as follows: 24, 20, 24, 20, 21, 25, 27, 25, 20, 22.

PERMANENCY

The life of these cusps is ordinarily very short. They are formed only under a peculiar set of conditions, and if these conditions are changed the cusps are destroyed. The larger cusps are, of course, more stable than the smaller ones, because the main mass of them is farther back on the beach and can be reached only by the larger waves. The smaller ones seldom last more than one or two days at most, unless the lake is remarkably quiet. On more than one occasion the writer has found that cusps which were formed in the morning disappeared before noon because of changing conditions on the lake during the forenoon.

RELATION TO DIRECTION OF WAVE

It has been mentioned that cusps are formed only under peculiar conditions. Chief among these, as pointed out by Johnson[1], is that the waves must strike the shore essentially parallel to it. Nothing has been observed by the writer along the Evanston beach to refute this argument. In fact, all observations support it very strongly. The destruction of cusps previously mentioned has been traced, in the majority of cases, to conditions which caused the waves to change their direction so that they came into the shore at an angle rather than parallel to it. Only in very rare cases has the writer observed cusps formed by oblique waves, and here the angle with the shore was very small. The ideal wave for cusp formation along the Evanston beach is a low, gentle swell which everywhere breaks along the beach at practically the same instant.

RELATION TO HEIGHT OF WAVE

The part played by the height of the wave is very pronounced in determining the distance between the apices of the cusps. For conditions along the Evanston beach the following conclusions regarding this relation appear to be approximately correct:

Height of wave *Inches*	Average distance between apices *Feet*
5– 6	6
7– 8	10
12–14	15
18–20	22

[1] Johnson, D. W., Beach Cusps, Geol. Soc. Amer. Bull. XXI, p. 614, 1910.

It will be recalled that for the individuals of the smallest and largest set of cusps observed the average apical distances were 6 feet and 22 feet, respectively. It appears, then, from the figures given above, that the apical distance is directly proportional to the height of the wave. This same conclusion was reached by Johnson[2] some years ago, but the figures given here are based upon observations by the writer.

Waves higher than 18 or 20 inches are frequently found on Lake Michigan, but the writer has not observed cusps formed by them.

From the above it will be seen that the cusps are also often destroyed by the waves merely changing their height as well as their direction. This is especially true if the waves grow larger instead of smaller.

RELATION TO DIRECTION OF WIND

The direction of the wind is a factor in cusp formation in that the wind generates the type of wave that either brings about the formation of cusps, destroys them, or prevents their formation entirely. Inasmuch as cusps are seldom formed unless the waves come in parallel to the shore, it follows that winds giving rise to oblique waves are the ones bringing about the destruction of cusps or preventing their formation. It is easily seen, then, that for the west shore of Lake Michigan winds other than almost due east or west would not likely generate the proper kind of waves for cusp formation. Winds directly from the east are rare in Evanston, but west and southwest winds are common. It has been found that the best time to find cusps on the Evanston beach is a few hours after a pronounced low-pressure area has passed, that is, during the comparative calm immediately preceding a "high" of ordinary intensity, or a short time after the "high" has passed. In the first case the wind will be from the west, with the result that the waves will run counter to the wind as low swells and break parallel to the shore; in the second case the wind will likely shift to almost due east, especially if the next approaching "low" has its center far to the south of Evanston.

[2] Johnson, D. W., op. cit. p. 610.

RELATION TO TIME OF YEAR

Cusps along the Evanston beach are of very frequent formation at all times of the year except in the dead of winter. From the latter part of December until early March, cusps are only occasionally formed. This is because of the fact that during the winter months the water in the sand and gravel along the shore is commonly frozen. Also, mush ice, thrown up by waves, and drifting snow accumulate as a solid wall against which the waves break instead of against the shore. Again, large ice floes often drift against the shore and stop all wave action as long as they remain there. For these reasons cusp formation is reduced to a minimum during the winter.

It is believed that cusps are formed more abundantly in late summer and early autumn than during the spring because of greater freedom of the lake from strong north and northeast winds.

ORIGIN OF CUSPS

Numerous hypotheses by Branner[3], Jefferson[4], Johnson[5], and others have been set forth to explain the origin of cusps, but that of Johnson seems best in accord with the available evidence. The writier will go no further than quote briefly Johnson's theory. It is as follows: "Selective erosion by the swash develops from initial irregular depressions in the beach shallow troughs of approximately uniform breadth, whose ultimate size is proportional to the size of the waves and determines the relatively uniform spacing of the cusps which develop on the inter-trough elevations."

CONCLUSIONS

1. Cusps are formed abundantly on the Evanston beach at all times of the year except in the dead of winter.

2. They are very seldom formed except when the waves strike parallel to the shore.

3. Waves parallel to the shore are most frequently generated when the wind is from the east or west. This takes place when a "low" is approaching, or just after its center has passed.

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[3] Branner, J. C. Origin of Beach Cusps, Jour. Geol., Vol. VIII, pp. 481-484, 1900.
[4] Jefferson, M. S. W., Jour. Geol., Vol. VII, pp. 237-246, 1899.
[5] Johnson, D. W., op. cit., p. 620.

4. The distances between the apices of the cusps in a particular set is approximately in direct proportion to the height of the waves.

5. The cusps are composed of any kind of material available, but it is the general rule that the larger ones are composed of coarser material than the smaller ones, and the cusps are of coarser material than the intercusp areas.

6. Cusps last for only a few days at most. The smaller ones are generally destroyed in a few hours by the waves changing their direction or height.

7. Cusps are developed by the selective erosion of the swash from initial depressions on the beach. The scalloped shore line thus represents a delicate balance between wave erosion and deposition.

CORRELATION OF ILLINOIS COAL SEAMS WITH EUROPEAN HORIZONS

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Illinois State Geological Survey and University of Chicago.

A congress for the advancement of the studies in carboniferous stratigraphy was held in Heerlen, Holland, June 7-11, 1927, and the transactions of this congress, edited by W. J. Jongmans, were published a few months ago. I was invited to present a paper on the correlation of American and European coal seams at this congress, but declined, giving as reason that we are not yet quite ready to correlate American and European coal seams. This opinion was challenged by European paleobotanists and coal geologists, especially by W. Gothan of the Prussian Geological Survey in Berlin. I, therefore, communicated with Professor Gothan and sent him a collection of plant fossils from our coal No. 2 of Northern Illinois to see whether he could correlate the horizon of this coal with any coal horizon of western Europe. Professor Gothan informed me that the fossil plants of our coal No. 2 indicated the same horizons as can be found at Piesberg and Ibbenbüren of the Osnabrück district in Westphalia and also showed similarity with the flora of the layers of Saarbrücken in the Sarre district. This opinion was corroborated by Dr. Hans Bode, also of the Prussian Geological Survey, who had published a monograph on the flora of Ibbenbüren[1] and with whom I am also in correspondence about the subject. Dr. Bode intends to spend part of the coming year in Chicago studying my collections of the Pennsylvania formation of Illinois. I hope that our discussions will clear up a number of points concerning American and European coal correlations.

Besides having a representative collection of coal No. 2 fossils from Illinois on hand, Gothan and Bode used my paper on the Pennsylvanian flora of Illinois[2] for the comparison of their horizons with ours.

[1] H. Bode, Palaeobotanisch-stratigraphische Studien im Ibbenbürener Carbon, Abhandlungen der Preussischen Geologischen Landesanstalt Neue Folge, Heft 106. Berlin, 1927.

[2] A. C. Noé, Pennsylvanian Flora of Northern Illinois. Bulletin No. 52, State Geological Survey of Illinois, Urbana, 1925.

At the congress in Heerlen it was agreed to establish a new international nomenclature of the carboniferous formations of Europe. The lower carboniferous, which we call the Mississippian, is now uniformly called in Europe the Dinantien, and the upper carboniferous, our Pennsylvanian, is divided into three sections which are named, from bottom to top, Namurien, Westphalien, and Stephanien. The Westphalien is again sub-divided from bottom to top into the series A, B, and C, and the Stephanien is divided into a lower and upper series.

The horizons of Piesberg and Ibbenbüren in the Osnabrück basin of Westphalia, as well as the Flaming Coal and Fatty Coal of Saarbrücken in the Sarre district, belong to series C of the Wastphalien. Our coal No. 2 would, therefor, be correlated with the uppermost Westphalien of Europe, and the Pennsylvanian formation of Illinois, above Coal No. 2, would fall into the Stephanien. The latter is the uppermost series of the carboniferous formation in Europe and lies directly under the Permian. Our Pottsville would, therefore, correspond to the Namurien and series A and B of the Westphalien in Europe.

It is of interest to note that, according to Hirmer[3], all European coal ball horizons are below the Stephanien while ours are only in horizons corresponding to the European Stephanien. Also the coal ball floras of coal No. 5 of Harrisburg and of Grape Creek coal of Danville, Illinois, show a flora which is closely related to that of the Permian of Europe.

During a recent trip to Europe I had the opportunity to study the fossil plant collections of the British Museum in London and in some places in Westphalia and in the Donetz basin of Russia. My own observations agreed with those of Professor Gothan and Dr. Bode with regard to Westphalia. In the Donetz basin I had the opportunity to do extensive field work in the basin of the Khroustalskaya coal seam. Its flora corresponds to our No. 2 flora. The Khroustalskaya coal seam represents the uppermost Mouscovien of the Russian carboniferous, which in turn corresponds to Westphalien C of Western Europe.

The species which are common to the corresponding horizons of Westphalia, the Donetz Basin, and northern Illinois are:

[3] M. Hirmer, Uber Vorkommen und Verbreiting der Dolomitknollen und deren Flora. Compte Rendu, Congres pour L'avancement des Etudes de Stratigraphie Carbonifere, Liege, 1928.

Calamites suckovi
Annularia sphenophylloides
Calamocladus equisetiformis
Sphenophyllum emarginatum
S. majus
Alloiopteris sp.
Palmatopteris furcata
Mariopteris muricata
Neuropteris rarinervis
Cyclopteris orbicularis
Linopteris neuropteroides
Pecopteris vestita
P. arborescens
Alethopteris serlii
Trigonocarpus

It is to be hoped that before very long other fossil-bearing coal seams of Illinois will be correlated with European seams. The roofs of the following coal seams of Illinois contain excellent plant impressions which can be used for correlations:

Coal No. 1 of Rock Island
Coal No. 2 of Colchester
Coal No. 2 of Murphysboro
Coal No. 5 of Harrisburg
Coal No. 6 of Jackson County, Perry County, Franklin County and Williamson County
Coal No. 6 of Danville (Grape Creek Coal)

Coal balls with distinct floras have also been found in sufficient quantities in Coal No. 7 of Danville and coal No. 13 of Calhoun Richland County.

A NEW SHALE AND RELATED STRUCTURE IN THE CHICAGO AREA

DAVID O. TAYLOR
Northwestern University, Evanston.

A tunnel designated as the Chicago Avenue tunnel, now under construction by the City of Chicago, exposes a sequence of strata and a faulted structure unusual, if not unique, in the Chicago area. This tunnel is eighteen feet in diameter and when completed, will extend from a point three miles out under Lake Michigan west along Chicago Avenue to Harlem Avenue, a total distance of eleven miles. It is situated 180 feet below the surface of the ground at the shore of Lake Michigan, where a shaft to the tunnel passes through 135 feet of glacial drift and 45 feet of bed rock.

The bed rock exposed in the tunnel consists of a dolomite formation overlain by an interbedded shale and dolomite formation. The dolomite in the lower formation is greyish to buff, finely grained, and massively bedded, except near the top where it grades into laminae of agrillaceous dolomite. Grey shale, that represents an impurity, is sufficiently concentrated along the bedding plains to serve as partings. Stylolites are developed in the massive dolomite and they are capped by grey residual clay. The shale in the upper formation is uniformly green and very finely grained although it contains some grains of clear quartz as large as 0.2 mm. in diameter and some secondary pyrite. A few fossils of brachiopods and crinoid stems and arm plates have been found in the shale. The brachiopods have been identified by Dr. T. E. Savage as *Gypidula* n. sp., *Whitfieldella* n. sp., and one comparable to *Spirifer,* probably a new species. The dolomite that is interbedded with the shale is finely grained and nor-porous and occurs in continuous bands as much as 8½ inches thick. Thus, with respect both to character of rock and color of shale there is a marked difference between the formation below and the formation above the contact.

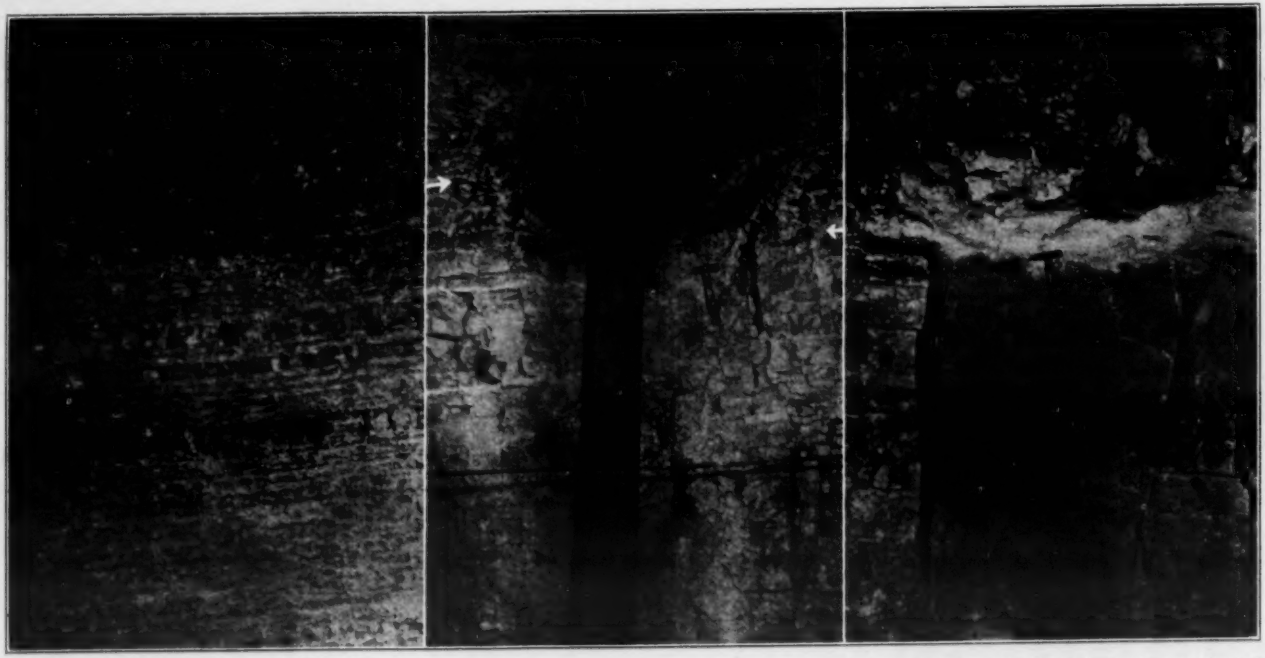
The contact is very even and regular. The thickness of the strata between the contact and key beds both above and below the contact are uniform within one and one-half inches over the 650 feet of exposed shale. All evidences indicate that the strata are conformable.

The shale formation lies in a graben, the total movement of which is estimated to be more than 40 feet. The movement is distributed along six normal faults, which are the major factors in the structure. The direction of movement can be determined by drag along the faults and by relative altitude of key beds. Minor joints and faults cut both the shale and dolomite formation where they are exposed in contact. In the east part of the graben a Y fault having a vertical displacement of eight inches, overlies a three foot opening in the dolomite, which is filled with breccia derived from the overlying shale with a subsequent infilling of the interstices with green shale. Consequently, it is definitely established that the opening was formed after the deposition of the shale, as faulting and brecciation of the shale and dolomite would be impossible while unconsolidated. It is, therefore, further evident that not only the major graben but the minor faults were developed subsequent to the deposition of the shale, and that the shale in the joints in the massive dolomite is derived by downward movement from the overlying green shale.

In the massive dolomite, pockets of green shale are uniformly distributed through the length of the tunnel. Many of these pockets are so large that timbering is required to prevent caving, and at one place, a zone 150 feet in length is so weak that concrete facing is required to retain it. The shale in the pockets is uniformly greenish in color and contains much disseminated pyrite. No bedding or banding is evident, but all of the shale is slickensided. Smoothed fragments of dolomite occur in the pockets in the matrix of shale, and the walls of the pockets are smoothed and horizontally fluted—a result of solution. In that part of the tunnel where the shale is exposed it is possible to trace a connection from the shale in the pockets and joints to the bedded shale above the dolomite as at the Y fault mentioned. In most places no such connection is observable, but it seems logical to assume that in all cases such connection exists. If this is true, the shale has an east-west extension of at least three miles, which is the present length of the tunnel.

It is generally accepted that the bed rock in the Chicago area is massive dolomite belonging to the Racine and Port Byron formations of the Niagaran series.[1] There is a complete conformable sequence of dolomite from the Joliet, the base of the Niagaran,

[1] Savage, T. E., Silurian Rocks of Illinois: Bull. Geol. Soc. Amer., Vol. 37, pp. 513-534, 1926.



Views of formations exposed in the Chicago Avenue tunnel. (*Left*) Lower five feet of shale. (*Middle*) Shale-dolomite contact, indicated by arrows. (*Right*) Shale pocket in dolomite. (*Photos by O. A. Seager.*)

into the Port Byron containing no shale comparable to this occurrence, which precludes that this shale be referred to an earlier horizon than the Port Byron. Dr. T. E. Savage[2] states: "The position of this shaly bed is certainly Niagaran, and it corresponds with the strata at Le Claire which overlie the Port Byron at that place." Accordingly, the massive dolomite in the tunnel is assigned to the Port Byron formation, and the interbedded shale and dolomite represent a post-Port Byron formation, of Niagaran age, conformable with the underlying formation. Because of the isolated occurrence of this shale member, it seems that a separate name should be tentatively given it. The term Chicago is proposed.

COLUMNAR SECTION OF CHICAGO AVENUE SHAFT AND TUNNEL.

	Feet	Inches
Pleistocene*—		
Sand	20	
Plastic clay	30	
Stiff clay	20	
Hard clay, small boulders	17	
Hard clay, large boulders	17	
Clay, sand, water	7	
Sand and water	2	
Clay, boulders, sand, water	19	
Unconformity Niagaran—		
Chicago—		
Interbedded green shale and dolomite	28	
Massive dolomite bed		8½
Interbedded green shale and dolomite	4	4
Massive dolomite bed		5½
Interbedded green shale and dolomite	4	3
Green shale		½
Port Byron—		
Laminated, argillaceous dolomite	3	1
Thin bedded dolomite	7	
Massive dolomite	14 plus	

* Pleistocene from the engineer's log of the shaft at Chicago Avenue and the lake shore.

CONCLUSIONS

1. There are two distinct, but conformable, formations of the Niagaran series exposed in the Chicago Avenue tunnel. The lower formation is designated as the Port Byron, the upper as post-Port Byron.

[2] Personal communication.

2. The present position of the shale formation is due to normal, graben faulting.

3. The shale pockets in the dolomite are filled with green shale derived from the overlying formation.

4. The shale formation is definitely determined to have an east-west extension of at least three miles.

ACKNOWLEDGMENTS

The author is indebted to Mr. G. D. Tompkins, engineer of the tunnel, who made possible the securing of the data; also to Mr. O. A. Seager for assistance in field work, and to Dr. George E. Ekblaw, associate geologist of the State Survey, and Dr. T. E. Savage, of the University of Illinois, for helpful suggestions in field work and writing.

ON THE OCCURRENCE OF PLATYCRINUS IN PENNSYLVANIAN STRATA OF WESTERN INDIANA*

J. MARVIN WELLER
State Geological Survey, Urbana.

The camerate crinoids with the exception of a single degenerate species of the peculiar genus *Acrocrinus* (*A. wortheni* Wachsmuth have long been considered to have become extinct in America at the close of the Mississippian period. It was with no ordinary interest, therefore, that I discovered in the summer of 1926 a locality in Warren County, Indiana, where a limestone, situated only a short distance above the base of the Pennsylvanian, as the system is represented in this region, is literally crowded in places with stem segments of the type which are ordinarily considered to be characteristic of the camerate genus *Platycrinus*. There can be no question as to the Pennsylvanian age of this limestone as it carries an unmistakable fauna including such species as *Chonetes mesolobus, Spirifer cameratus, Marginifera muricata, Hustedia mormoni,* etc.

The great numbers of these stem segments and their large size make them a striking feature of the fauna of this locality. An extended search was made in the hope that a calyx might be discovered but without results. No recognizable portion of any of these crinoids was obtained except the stems. In size the stem segments vary up to those having a greater diameter of nearly an inch, and in this they are unlike anything that is known from the Upper Mississippian. The Chester species of *Platycrinus* are neither large nor abundant, and stems having a larger diameter of more than one quarter of an inch are seldom if ever to be observed. These Pennsylvanian stems resemble in size those which sometimes occur in the Warsaw and Osage divisions of the Lower Mississippian.

The stem segments collected from this Indiana locality exhibit considerable diversity in regard to their various proportions and ornamentation. We know, of course, that the segments of a single crinoid's stem are not necessarily at all uniform. Segments of several types are sometimes intercalated with one another, or

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those at one end of the stem may differ notably from those at the other. From what is known concerning the stems of *Platycrinus*, however, it would appear that stem segments of different types do not occur adjacent to one another. Although the segments at various positions in the stem may be notably unlike. they are probably connected by an intergrading series. A consideration of the various types of segments obtained from this Indiana locality would suggest that more than a single species is represented, but of course this cannot be determined from the material in hand.

Most Paleozoic crinoids were gregarious and often lived in more or less compact colonies. The exposures at this Indiana locality represent the only known *Platycrinus* colony which existed in America during Pennsylvanian time. Of course, there were almost certainly others, but as no other has ever been reported they must have been very rare. In fact, the only locality in the world from which *Platycrinus* or any near relative of it has been reported from beds younger than Mississippian is the island of Timor situated some distance north of Australia. Here a great variety of crinoids have been collected from strata considered to be Permian in age.

The facts that the stem segments occur in such numbers at the Indiana locality and that no recognizable fragment of a calyx has been observed, suggest that these crinoids were long-stemmed forms and probably of considerably smaller size than one would expect from the size of some of the stem segments. Large crinoid stems of the ordinary circular type with a diameter of an inch or even more are quite common at many Pennsylvanian localities, and yet no calyx or even a single plate of a calyx of comparable size has ever been found. It is practically certain, therefore, that these stems were long (I recently collected a piece four feet in length and of a uniform diameter of one inch) and that they tapered very rapidly toward their upper ends, so that at the point of attachment with the calyx they may have been reduced in diameter by as much as seven-eights or even more. It is not at all improbable that these Pennsylvanian representatives of *Platycrinus* had this characteristic also.

The Carboniferous members of the family Platycrinidae were supported on stems entirely different in nature from those of any other Paleozoic crinoid. The segments of this stem are oval, or at least the surfaces by which they were joined together are oval. Down the center of this surface and marking the long diameter of

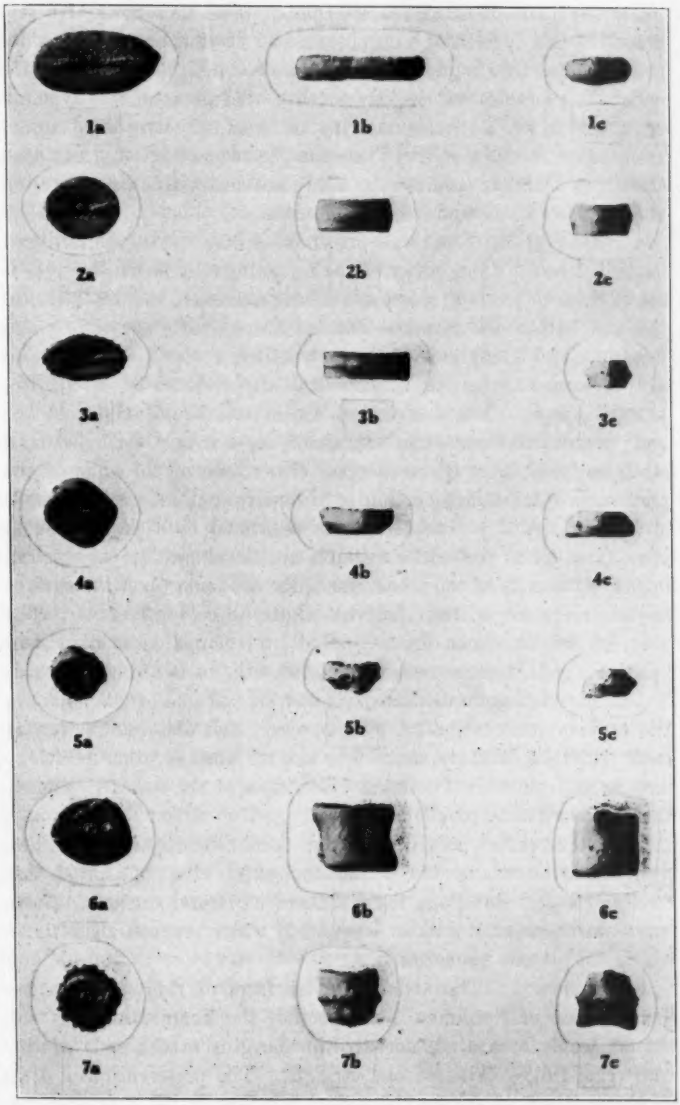
the oval extends an articulating ridge which is raised slightly above the lateral margins of the plate. Upon either side of this ridge lies a depression which is bounded upon the outside by the lateral margin of the segment and which was probably occupied by ligamental material during the life of the crinoid. Such an arrangement allowed a certain amount of free movement between each pair of stem segments with the articulating ridges acting as fulcra.

The articulating ridges upon the opposite surfaces of each segment are seldom if ever exactly parallel, and one may deviate from the direction of the other by any angle up to nearly 90°, although in most cases this angle is rather small. Each successive segment, therefore, is rotated through a certain angle when compared to its predecessor, and as such rotation is progressive a twisted stem results which is flexible and capable of movement in any direction.

The stem segments illustrated upon the accompanying plate and described in the following paragraphs possess in typical fashion the characters described above. They were all collected in a silicified condition from a dark lower Pennsylvanian limestone near the center of the north half of section 35, T. 21 N., R. 9 W., Warren County, Indiana.

Specimen 1. This specimen is of a type which is rather abundant. Its long diameter is almost exactly twice its short diameter, and its thickness is about one third of the latter. The articulating ridges of the opposite sides are almost parallel to one another. Many of the segments of this type are nodals and bear, at one end only, a circular facet for the attachment of a cirrus. These are of various sizes and may be quite small (as in the figured specimen) or so large that the segment becomes wedge shaped due to the thickening of the cirrus bearing end. No specimens of this type of segment have been obtained in a sufficiently perfect state of preservation to exhibit the details of their structure or ornamentation. The sides and ends, however, while convex, were probably smooth and unornamented.

Specimen 2. This specimen is of a type also commonly present. Its shape resembles that of the former except that this segment is considerably thicker in proportion. The articulating surfaces are also more deeply excavated between the transverse ridges and the lateral margins. Like the former, the articulating ridges are almost parallel. The margins of the articulating surfaces opposite the ends of the transverse ridges are raised into



Pennsylvanian Platycrinus Stems.

All natural size except two lower rows, which are enlarged 4 diameters.

about five pairs of elongated alternating teeth or sockets. No segments of this type have been observed to be cirriferous. The sides are expanded into rounded angulations, becoming obsolete near the ends whose profiles are slightly concave. Segments of this type are ornamented by a horizontal ring of short, closely spaced spines situated on the sides midway between the two articulating surfaces. One or two similar spines occur above and below this ring, forming vertical rows at the ends of the segments.

Specimen 3. This well-preserved specimen is proportioned quite differently from either of the foregoing. Its short diameter is about three-quarters as great as its long diameter, and its thickness is about half of the former. The transverse ridges are strong and flat-topped. The margins of the articulating surfaces are sharp and are separated from the ligamental depressions by a shallow parallel groove. The margins of the articulating surfaces at the ends are not rounded as in Specimen 2, but are flattened and straight for a short distance upon either side of the ends of the transverse ridge. This portion of the margin is raised into small, closely set, radially elongated teeth separated by sockets of equal size. The teeth and sockets which are developed at the margin opposite the ends of the transverse ridge continue upon the surface of this ridge for at least half its length toward the center. The sides of this specimen are expanded into elongated median convexities which becomes nearly obsolete as the ends are approached. A pair of small spines situated side by side at one of the ends are the only ornamentation of this segment, and its preservation is such that it is unlikely that other similar ones at other positions have been destroyed. The transverse ridges of the two articulating surfaces are nearly parallel.

Another rather poorly preserved specimen of nearly similar proportions is ornamented by a horizontal ring of spines encircling the segment along the middle of its lateral surfaces. These spines are somewhat coarser and more widely spaced than those which are present upon Specimen 2.

Specimen 4. The articulating surfaces of this specimen resemble those of Specimen 3 except that the ligamental areas are not so deeply excavated, nor are the margins at the ends of the transverse ridges flattened and straight. The preservation of this specimen is not good enough to show whether or not a groove was present just within and parallel to the margin, but there is no trace of it remaining. Remnants of the fine radial teeth and

sockets are preserved upon the flat surfaces of the transverse ridges to a position nearly half-way to the center. This specimen differs from all of the foregoing by virtue of the strong rotation of one articulating surface with respect to the other, so that the transverse ridges intersect at an angle of about 68°. This segment is thin, compared to either Specimen 2 or Specimen 3. The sides are smooth and are unornamented save for two irregular pustules. These do not resemble the spines mentioned in connection with the foregoing specimens, and they may have supported small cirri although this is far from certain.

Specimen 5. This specimen resembles the last in a general way, as the proportions of the long and short diameters of the articulating surfaces and the amount of rotation of one with respect to the other are about the same. This segment, however, is proportionally thicker, and the ligamental depressions are deeper, but the details of the articulating surfaces have been largely destroyed. The most conspicuous difference, however, between this segment and Specimen 4 consists in the presence of a spinose, angular ridge which extends around the segment at the middle of the sides and gives it a nearly circular outline. The spines which stand upon the crest of this ridge are small, rounded, and unevenly spaced. Additional spines of a similar nature occur in small triangular areas, the apices of which meet the margins of the articulating surfaces at the ends of the transverse ridges.

Specimen 6. This specimen, the illustrations of which are magnified four diameters, possess articulating surfaces whose proportions are about equal to those of Specimen 3. This small segment, however, is very much thicker in proportion than any of the foregoing. The articulating surfaces are nearly flat. The margins are only very slightly raised above the ligamental areas, and the transverse ridges are low and divided down the center by a rather prominent groove or socket, which transforms this ridge into two equal tooth-like processes. The lateral surfaces are smooth and extend straight from one articulating surface to the other. The ends, however, possess a concave profile, thus giving the segment a constricted appearance when viewed from the side. One articulating surface is rotated with respect to the other through an angle of about 14°.

Specimen 7. This small segment, the illustrations of which are also enlarged four diameters, greatly resembles Specimen 5. It differs principally in its greater relative thickness, in the

relatively coarser nature of its spines, and in the rotation of one articulating surface with respect to the other through a somewhat greater angle, being in this case about 73°. The margins of the articulating surface of this specimen are raised very slightly if at all. The ends, however, are higher than any other portion of these surfaces, thus giving them a concave profile when viewed from the side. The articulating ridges are rather weak and are cut by a prominent notch at their outer extremities, thus producing two small tooth-like processes. Only one faint spine is present between the encircling ring of lateral spines and the ends of the transverse ridges. The other three areas, which are occupied by triangular groups of spines in Specimen 5, are smooth in this segment. Stem segments of this type are strongly reminiscent of the Ste. Genevieve species, *Platycrinus penicillus* Meek and Worthen.

THE SCIENTIFIC SEARCH FOR UNDERGROUND WATER*

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Many cities and large industrial plants in Illinois are faced with the problem of finding increased supplies of good water. In every case two major possibilities must be considered: sinking a well or several wells to a water-bearing rock formation, and impounding surface water in a reservoir. Inasmuch as the impounded surface water is much more expensive than well water—on account of the first cost of buying land, constructing a dam, and building a filter plant, and the continuous cost of treatment after the improvement is completed—an attempt is usually made to secure water from an underground source if it is obtainable in large enough quantity and of sufficiently low mineral content. Failure often results in this search because there is no water-bearing rock formation to yield the desired supply, but in some cases a potential supply is not discovered because of a lack of understanding of the geological conditions governing the location of the water-bearing deposit. Every locality has its peculiar set of geological conditions, the understanding of which is very important in the fullest development of the underground water resources.

BED ROCK

The availability of an underground water supply depends upon the geographical location, depth, thickness, extent, and porosity of the water-bearing deposit. Important data on the character of the subsurface material at any proposed location can be obtained from a study of drilling records already on file at the State Geological Survey. It is possible indeed, to predict with some degree of confidence the water possibilities of a well into the consolidated bed rock formations at any place in the northern third of the state, because of the compilation of numerous records of wells and the publication of several geologic and water reports on the region. The bed rock formations generally maintain their

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characters through long distances, but there are a considerable number of exceptions which make geologic advice previous to and during drilling high desirable.

Throughout northern Illinois the St. Peter sandstone is a prominent aquifer; nevertheless it yields but little water in the vicinity of Chicago because it is already too heavily drawn upon by wells in the region. At Gardner, also, the sand is so fine-grained and closely packed that a well to the St. Peter has proved a failure. East of Des Plaines the rocks have been faulted, so that, when a well to the Cambrian sandstones was attempted, it was necessary to run the casing down to the bottom of the hole as drilling proceeded, in order to protect the well from filling up with the caving broken rock; as a result, when the well was finished, all water was likewise effectually cased out. In contrast to these illustrations of undesirable conditions, there is in the vicinity of La Salle a sandstone formation lying under the St. Peter, known as the New Richmond standstone, which reaches a known thickness of 188 feet and is an important aquifer in that region; laterally it thins rapidly to a thin layer of dolomitic sandstone which carries very little water.

GLACIAL DRIFT

The problem of finding water-bearing sand and gravel deposits of suitable extent, thickness, and porosity in the glacial drift is more complicated than the study of bed rock aquifers. The drift deposits, being much more irregular in location and extent, require not only a comparison of available well records but a field study of the topography, streams, rock outcrops, drift exposures, springs, and local wells of all kinds for several miles in all directions from the place of demand. Chemical tests of water from significant wells in the community are also important. The survey should not only reveal all known sand and gravel deposits, but provide a knowledge of the Pleistocene history of the region which will lead to the discovery of deposits not directly apparent. Such studies have often yielded very satisfactory and at times spectacular results. Almost the entire southern two-thirds of Illinois must rely for city water supplies upon glacial and recent sand and gravel deposits or impounded surface water, as the water in the bed rock is usually very highly mineralized. Although it is recognized that for many cities no amount of prospecting will disclose

an adequate supply of underground water, especially those further south, for some cities there still lie hidden large supplies or water of better quality than have yet been obtained.

TAYLORVILLE

The most recent successful search for a better underground water has just been completed at Taylorville. An entirely adequate supply can be obtained from the two wells now in use there, but as the water contains an average of 682 parts per million of hardness it was hoped by city officials that a water of better quality could be found. Accordingly, the State Water Survey and the State Geological Survey were requested to study the situation and recommend locations for test holes.

A comparison of numerous coal test records on file at the Geological Survey revealed the fact that a preglacial valley extends in a northeast-southwest direction across Christian County through Taylorville as shown by the contours in figure 1. The logs also indicated that numerous and thick beds of sand and gravel are present in the drift above the bed rock. The conditions are emphasized in the field by the lack of bed rock outcrops in all valleys for several miles from Taylorville, the presence of outcrops outside the area of the preglacial valley, the presence of sand and gravel beds exposed in cut banks of drift in the area, and the locations of several springs. Thus it is apparent that the region of this preglacial valley was at one or more times the site of deposition of sand and gravel poured out by glacial streams.

Inasmuch as the investigation was made primarily to locate a water of better quality, a number of samples of water were taken from significant wells in the vicinity and were analyzed by the State Water Survey. It was found that the water is progressively softer toward the northeast part of the city, where the Hopper Paper Mill and Wabash Railroad wells yield water with a hardness averaging 200 parts per million. Four test holes were drilled in different directions from the Hopper Paper Mill at distances of over 1000 feet, and samples of the material encountered were saved at depth intervals of five feet or less. Each new location was made only after a careful study of the samples and a correlation of materials from the preceding wells.

The test holes revealed the fact that the "glacial sand and gravel deposit," indicated in figure 1, which supplies water to the

various wells in the city, has filled to the brim and obliterated all traces of a valley in the glacial drift, more than half a mile wide and 100 feet deep, extending in a northeast-southwest direction along the line of the bed rock depression. The coarsest part of the gravel deposit was found at the bottom in all test holes, and the largest pebbles and greatest thickness of coarse material were found in the test hole farthest northeast.

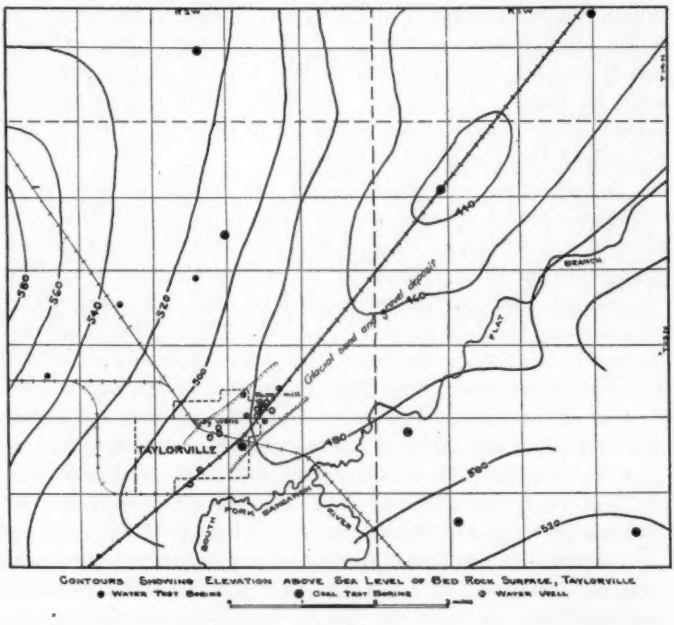


FIG. 1.

The water of lowest mineral content came from the northeast test hole, a sample taken from the bottom of the hole having a hardness of 215 parts per million. It is thought that the water in the gravel may flow from northeast to southwest through coarser to finer material, dissolving minerals as it goes, thus producing a water of highest mineral content in the southwest. If the interpretations are correct, a well drilled northeast of the Hopper Paper Mill will assure the city of a large continuous supply of water having a lower mineral content than the water now used.

MATTOON

The situation at Mattoon not only illustrates a different type of glacial sand and gravel outwash deposits but also shows how results might be obtained even when the situation looks unpromising. During the last five years the Central Illinois Public Service Company has been trying to find an additional supply of water for the city. Under the direction of Mr. J. A. Rue, Division Engineer, over thirty-five test holes have been drilled in an attempt to locate a thicker portion of a sand and gravel bed which had been noted

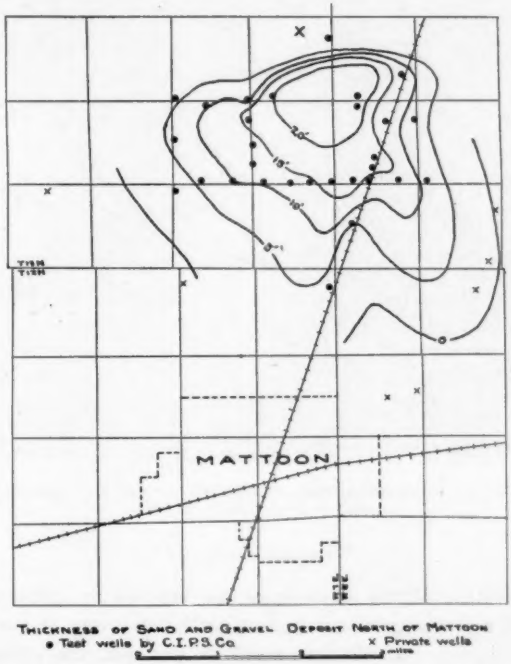


FIG. 2.

in several wells as being a few feet thick and lying on top of an old soil at a depth of from 35 to 50 feet. The search took them five miles north of Mattoon, where the deposit was found to thicken to over 20 feet, spreading out in a fan from the thickest portion at the northern edge as shown in figure 2. The fan occupies an area of approximately nine square miles, and pumping tests seem

to indicate that a larger supply of water has been located than is now used for the city. It is probable that the deposit was made by a debris-laden glacial stream pouring out from the ice while the ice-front stood stationary for a time at the northern edge of the deposit. It was later covered over by the advancing glacier, and no trace of it was left on the surface of the drift when the ice finally retreated.

FIG. 3. Topographic map of Western Springs and vicinity. Scale: 1 inch equals ¾ mile.

WESTERN SPRINGS

In neither of the above cases did the nature of the present topography give suggestions leading to the discovery of the water-bearing deposit. At Western Springs, however, the topographic map, shown in figure 3, suggests a possible favorable situation. Flagg Creek valley, lying west of Western Springs, was apparently cut by a larger stream than the present Flagg Creek. It is inferred that a larger stream once flowed through the valley and might have deposited important beds of sand and gravel. In fact, a record of a well drilled for bedrock water in the middle of the valley shows 28 feet of gravel on top of the Niagaran

dolomite. It was, therefore, recommended to the city, which was seeking relief from a water of high mineral content derived from the Niagaran dolomite, that several test holes be drilled across the valley to determine the nature and extent of a possible gravel bed. Such an investigation is now in progress.

COOPERATING AGENCIES

The State of Illinois has two agencies cooperating in the search for underground water supplies: the Geological Survey, which considers the geological situation, and the Water Survey, which studies the chemical character of the water and the quantity available. Thus it is possible for a municipality to obtain a complete survey of all the natural aspects of a proposed water-supply development.

THE GEOLOGICAL HISTORY OF THE MACOMB REGION

T. E. SAVAGE
University of Illinois, Urbana.

There was a man sent from God whose name was Louis Agassiz. The same came to bear witness to the divine things in Nature; to open the eyes of men to her beauties rare which knowledge makes more charming, and their ears to voices sweet which speak of a long distant past; to quicken in the mind a deeper reverence for the revelations and the lessons which "half-revealed and half-concealed" are written over all the earth on which we live.

"All is holy ground,
And every flowering bush is aflame with God."

On the fiftieth birthday of this great teacher the poet Longfellow wrote some verses in which Nature is represented as taking the child Agassiz upon her knee, and saying:

"The earth is a story book
Thy father hath written for thee.

Come wander with me, she said,
Over hills so often trod;
And read with me what can be read
From the manuscripts of God."

It is a fragment of the story from these manuscripts of which I shall speak at this time; a story as beautiful as it is strange and wonderful, and as wonderful as it is true; facts which Nature is ever willing to tell to him who lends an attentive ear.

Our story will deal with little more than the latter third of the earth's history, the records of the earlier chapters being exposed in other parts of the continent. We will begin with the oldest rocks that have been penetrated in the deep wells in this area. These belong to the Ordovician period, and were laid down as sediments in a sea that covered this region something like 500 million years ago. At that time, over the place where Macomb now stands, was a great central sea which advanced from the

south and southwest across Illinois, and extended north as far as the highlands of central Wisconsin. The clear waters of such shallow seas were veritable gardens of marine life, in which there flourished a great number and variety of animals that were fixed to the sea bottom, and so secreted calcareous skeletons or shells as a protection from their predaceous enemies. As each generation of such animals lived and died, their more or less broken shells accumulated on the ocean bottom, and formed the floor on which their successors became established. These, in turn, at death gave up their shells to swell the deposit on the ocean bed. In this manner, throughout slow moving centuries, there was accumulated a thickness of more than 500 feet of sediments known as the Lower Magnesian or Prairie du Chien limestone.

Such deposition was brought to a close by the withdrawal of the sea from some cause, probably the down warping of some part of the ocean bottom. Into this deepened basin the waters drained from the lands, and the larger part of the Continent, including Illinois and the Macomb region, emerged from beneath the sea.

Concerning the life that peopled this ancient land, little is known. During millions of years in the early periods of the earth, almost all of the plants and animals lived in the water. Low forms of moisture nurtured plants had possibly succeeded in establishing themselves on the lands before this time, but no animals are known to have yet become adapted to terrestrial habitats.

After a long interval of land conditions during which the surface was gradually lowered by the slow but continuous processes of weathering and erosion, the sea again advanced over the trenched and denuded surface of Illinois. At this time the bordering lands were so high that the streams which drained them carried large quantities of sand into this part of the basin. These coarse sediments were spread widely by the waves, and accumulated in places to a thickness of 200 or more feet. They make up the St. Peter sandstone formation, which is the source of the water of the deep well at Macomb, and of many other deep wells in the upper Mississippi valley.

After a long time the bordering lands became reduced in height, the streams carried less sediment, and shelled animals again flourished in great profusion in the shallow sea of this region. Among these, bryozoa and brachiopods were abundant; the flower-like crinoids and delicate corals were in places common; and cystoids and trilobites were never so numerous before or since.

Giant cephalopods with straight, chambered shells several feet in length were easily the masters of those ancient seas. Here for the first time appeared the earliest fishes in small forms which showed slight promise of becoming the founders of the highest dynasty of animals.

Then, as now, life was constantly changing in adjustment to the changes in its physical environment. These animals were all different from those that lived during Prairie du Chien time. Not a single species of the earlier age continued to live unchanged in these later seas. The shells of unnumbered generations of animals accumulated on the sea bottom and make up the Plattin and Kimmswick, or so-called Trenton, limestone of this region.

At the end of this long submergence the sea again drained from this part of the Continent, and there followed another long interval of land conditions. These land conditions preserve less fully the history of a region than do the times of submergence. The records of the past are written mostly on the deposits of the successive ages and in the fossils that they contain. They were impressed upon the sediments as they were slowly spread out on the sea bottom. Land areas commonly leave scant history of the life that peopled them. Even the bones and hard parts of the animals that die on the surface, and the trees that fall in our forests completely disintegrate and decay when exposed to the air, and leave no trace behind. The chief record left on a land surface during a long lapse of time is in the erosion it has suffered, and other things being equal, the amount of denudation is a measure of the interval of time.

After a long emergence the sea again slowly advanced upon the lands, at first from the south, and later, also from the north. The greater part, or all, of Illinois was submerged, and with it the Macomb region. During most of this time the sea was muddy, and the sediments that make up the Maquoketa shale were laid down in this region to a thickness of 180 to 200 feet. This sea withdrew from Illinois somewhat earlier than from farther east in North America. The emergence brought the Ordovician period to a close, and in restricted tracts of shallow seas along the borders of the continents the intense crowding and competition among the animals adapted to living in shallow water resulted in the extinction of great numbers of Ordovician types. Others which possessed greater plasticity and powers of adjustment became changed into species characteristic of the Silurian period. Land

life was still rare and simple in this far-off time. No air-breathing animals are certainly known, and only the lowest types of plants were becoming weaned away from their ancestral aquatic habitats.

The streams that drained the land of this region in early Silurian time deposited sand along their channels, and these narrow belts of channel sand, called the Hoing sand, are the reservoirs from which the oil and gas is produced in this part of the state.

Early in Silurian time an oscillating sea advanced into this region from the south, and extended as far as the northern border of Illinois. Other invasions from the north and east occurred in places on the continent during this Alexandrian epoch. During the succeeding Niagaran epoch the Silurian flood reached its height. In the Mississippi valley the sediments of this time were mostly limestones which in places reach a thickness of 300 to 400 feet, but in McDonough County they are less than 50 feet thick.

In these seas both simple and compound corals were abundant in many places. Brachiopods, cephalopods, and trilobites continued in new species, and cystoids which were waning and crinoids which were increasing were common in the late Niagaran seas. The primitive sharks were also on the increase at this time.

Near the end of the Niagaran epoch the sea was again drained from this region and the Mississippi valley, and land conditions prevailed here for a few hundred thousand years. On the lands some animals began to develop the air-breathing habit, and forms like scorpions and centipedes appeared for the first time. Land plants were still of low types of algae and their relatives, but the time of their expansion was near at hand.

At the end of this long land interval an Arctic sea advanced southward over the Macomb area and as far south as Jersey and Calhoun counties in early upper Devonian time. These waters were generally so warm and clear that corals built reefs, and brachipods were so numerous that their shells formed beds of limestone all the way from Alaska and the Mackenzie River to central Illinois.

Another short sea withdrawal succeeded this limestone deposition and was followed in late Devonian time by the advance of a stagnant sea in which foul mud, black with organic matter, accumulated over the larger part of the state. These sediments make up the Sweetland Creek shale.

Besides the numerous invertebrate groups that flourished in the Devonian seas, fishes were at this time abundant. Among these, primitive armored forms were common, and sharks, ganoids, and lung fishes abounded in such numbers that the Devonian has been called the Age of Fishes.

Impelled by the arid climates of late Silurian and Devonian time, some of these fishes formed the habit of gulping air into their swimming bladder which thus became modified into a lung. Limbs were also developed from their lobed, paired fins as the fishes crept about on the land in search of new water bodies, when the pools in which they previously lived became dry, and thus Amphibia arose from the fishes in the Devonian period.

Land plants were also making rapid progress in the development of vascular tissue consisting of specialized cells for the purpose of efficiently conveying the liquids through the roots and stems. This tissue made it possible for the first time for plants to grow to a considerable height above the ground, and forests have covered portions of the lands from this time. During the Devonian, ferns, lycopods, and rushes were common trees of the lowlands, and Gymnosperms consisting of seed ferns, the ancestors of the cycads, and Cordaites, the fore-runners of the conifers, formed the forests of the more moist uplands.

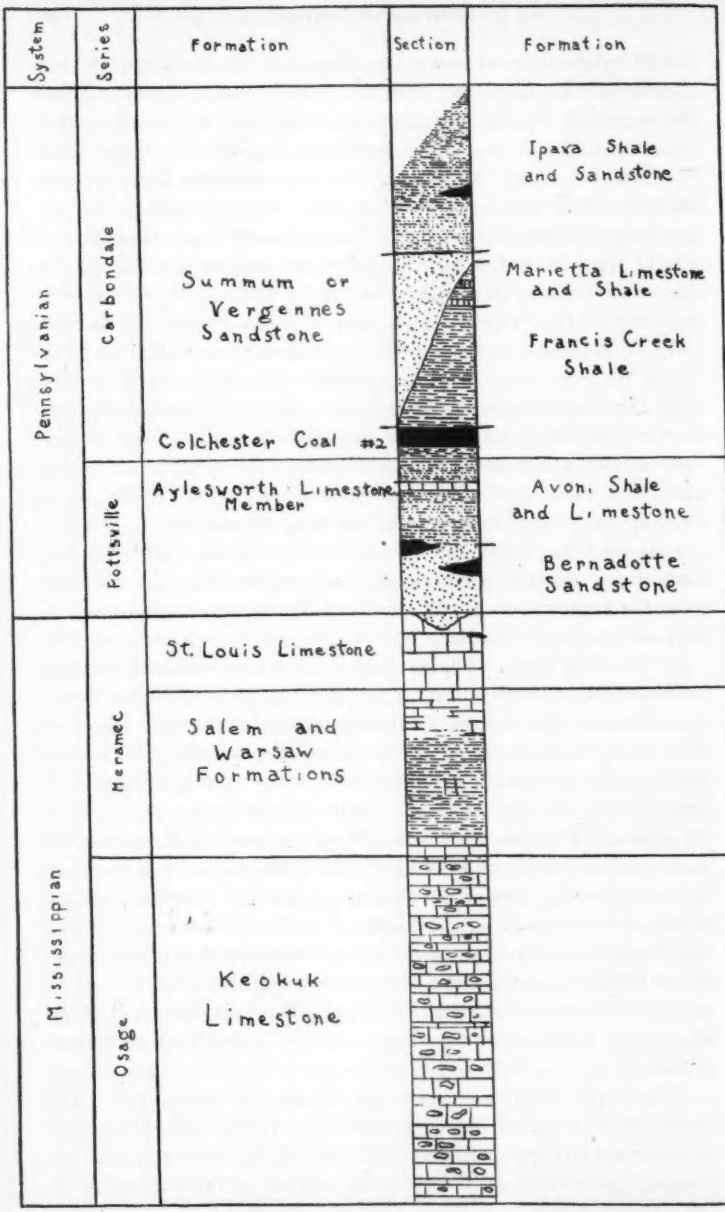
After a relatively short sea withdrawal, deposition of the Mississippian sediments in this region was initiated by the advance of a sea in which the muds of the Kinderhook shale were deposited on the earlier, darker shale of the late Devonian. The more or less weathered, upper portion of the black shale was reworked by the advancing Kinderhook sea and mixed with the muds brought to this basin by the streams. In this way there was developed in places what resembles a gradual transition from the black shale below into the greenish Kinderhook shale above. Towards the end of Kinderhook time the water became clearer, and the mud deposition gave place to the accumulation of shells and fragments of crinoids which make up the Burlington and Keokuk limestones. Near the end of Keokuk time the waters became more turbid and the calcareous shales of the Warsaw and Salem formations were deposited above the Keokuk limestone. No unconformity is clearly distinguishable in this region either between the Keokuk and the Warsaw, or between the Warsaw and Salem, although in Iowa a break in sedimentation is thought to have occurred at both of these contacts.

The deposition of the Salem sediments was followed by that of the St. Louis limestone, with only a short hiatus between them. The record of the Mississippian period in this region ends with the retreat of the sea to the southward in late St. Louis time. The area that is now McDonough County rose again from beneath the water and was exposed for another long interval to all the denuding influences to which the present lands are subjected.

At the end of this long period, slow warping movements, or some other causes, permitted the sea to again invade this area from the south. The southern part of the state was submerged in early Pottsville time, but the sea did not reach the Macomb region till near the end of this epoch. The valleys and ravines which had been formed were promptly filled with sediment, and during this, the Pennsylvanian period, the surface was deeply covered with a mantle of mud and sand. The first deposits were coarse and made up the Bernadotte sandstone, which was followed above by more shaly sediments of the Avon formation.

At times the water was shallow, and was bordered by low-lying lands which enclosed great lagoons and marshes. In these swampy areas there grew a rich and luxuriant vegetation, such as only a mild and moist climate can produce. Ferns, rushes, and lycopods —all flowerless forms in types long since extinct—formed jungles in these shallow swamps. As generations of these plants followed one another in long succession, their leaves and trunks and branches fell into the shallow water, and were buried out of the reach of the decomposing agencies of the air. In such a way thick deposits of plant debris were accumulated. With intermittent subsidence of the region, the sea returned and spread the muds and sands that occur upon and between the beds of vegetable matter, and as often withdrew leaving conditions that permitted the shallow swamps to occupy the areas it had previously covered. These buried accumulations of plant material were slowly transformed into coal beds, as the Colchester coal, from which today are unearthed the accumulated treasures of that distant age. The succession of strata exposed in this region is shown in the generalized columnar section.

Upon the deep foundation of sedimentary rocks above described, there is spread the loose mantle of soil and surface material on which our present civilization is built. Each successive layer of this foundation was at one time the surface of the sea bed, and



Generalized columnar section of hard rocks exposed in the Macomb region.

makes up a separate page in the history of the world's book of life. Each separate formation is a vast cemetery or mausoleum which contains the remains of the particular forms which constituted the life of the earth during each successive period.

These strata then can teach us many things. They tell us of time lapses inconceivable. They tell us of the myriads of strange forms that have appeared and played their part upon earth's stage, and disappeared behind the dim horizon of the past.

"Those that tread the globe
Are but a handful to the tribes
That slumber in its bosom."

They also tell us of continuous progress in the forms of life from age to age, and they reveal the slow and silent changes, "never hasting" but yet "never resting," by which the earth with all its richness and variety of living forms came to be as we find it today.

Deposition of the Pennsylvanian period in this region was brought to a close by a movement of the earth's crust which was connected with the beginning of the uplift of the Appalachian mountains in the east, and the Ozark dome to the south, and this area has never since been covered by the sea. As the land rose, the streams immediately began to carve new channels, and in the course of later centuries the surface of the land was dissected with valleys, and hills were left standing in bold relief above them.

During the long periods which followed this emergence, embracing all of the Mesozoic and the greater portion of the Cenozoic eras, the surface of this region was subjected to erosion rather than deposition. As a consequence, no record was here preserved of the monster reptile hordes that ruled the earth during the Mesozoic era, nor of the strange toothed birds that rivaled these winged reptiles for the supremacy of the air during that same period.

In order to read the history of the animals and plants that lived during this long interval, we must search farther westward for the later seas and find in their deposits, and in the sediments of the rivers that drained the lands, the more continuous record of the world's advancing life. From these we learn that during the Mesozoic era MacDonough County was a part of that great theater in which was displayed the scenes and actors of the wonderful drama of reptilian evolution. Here disported the largest reptiles that ever walked the earth, and here too, among their children were the strangest birds that ever found the empire of the air a refuge from

their enemies. During this same era also the highest offspring of that great reptile horde appeared, and primitive mammals took their place upon the earth—among the latest, yet destined to become the mightiest of all their mighty ancestors.

In the Cenozoic era the Placental mammals underwent a wonderful development, and became adapted to almost all the habitats the earth afforded. They soon became the dominant animals, and since that time have held undisputed sway.

During a long time in the Cenozoic era perpetual summer reigned in this region. Over the surface of McDonough County rich forests, many of the trees of tropical species, grew in great luxuriance. Birds of brilliant plumage lived and nested among those tree tops. Troops of monkeys found in those same forests a safe shelter and habitation, carnivores related to the cats and saber-toothed tigers crept stealthily through the jungles in search of food, and herbivores such as the camel, elk, horse, tapir, and rhinoceros found pasturage over the grassy prairies.

These happy conditions of the Cenozoic time were slowly brought to a close by an upward movement of the land, and some cause or combination of causes resulted in the lowering of the temperature over the greater part of North America. Immense quantities of snow accumulated far to the northward, and the warmth of the winter's sun sufficed only to compact it into more solid ice. As the quantity of snow increased, the pressure of the great weight pushed outward on all sides the edge of the mass of ice. Slowly from year to year the snow increased, and slowly the margins were crowded farther and farther outward. As this great mass of ice moved southward, the animals that here had lived and flourished were compelled to migrate farther south in search of a more genial climate, while desolation dreary and artic brooded over the region of McDonough County. Slowly the giant glacier moved forward with resistless force, unheeding alike the rocky point or rounded hill or river gorge. The surface of the ledges were ground off and polished by the stones that were carried along beneath the mass of moving ice, and these same stones, held fast beneath the ice, were planed and polished by the same friction. Year after year the depth increased, and for centuries our deserted land was locked in the embrace of ice.

After a long lapse of time the weakened rays of the sun increased in power, and causes combined to melt the ice from the frozen continent, and once more the pulse of Nature coursed along

the streams. Slowly this ice sheet, which was probably the Kansan, retreated in the direction from which it came, and around its retiring margin followed close a new influx of life into this region. On the surface over which it passed the ice sheet left a mantle of unsorted clay, sand, pebbles, and bowlders called drift or till. The gorges and valleys were buried deep beneath this load of drift, and slowly this new surface became clothed with a garment of vegetation.

For another long interval, known as the Yarmouth interglacial age, this region was subjected to the wasting effects of weathering and erosion, during which soils and beds of dust and organic material developed over the more level areas. The climate of this time was not so warm as it had been before the glacial epoch, but horses, tapirs, bison, deer, mastodons, and saber-toothed tigers still found congenial conditions for existence in this region.

Gradually there was a return of the causes that favored the accumulation of snow in the north, and another great glacier crept slowly southward and buried this region once more under a thick mass of ice. This was no sudden calamity burying all of the life beneath its ruins, but the animals had ample time to escape southward before the advancing destruction. This is known as the Illinoian ice sheet. It extended nearly to the southern border of Illinois, and pushed a lobe across the Mississippi River between Clinton and Keokuk for a distance of a few miles into Iowa. After a long stay this glacier, like the former one, slowly melted backward towards the north, and left another sheet of glacial till over the surface which it had covered.

To these glaciers we are indebted for two very important results. First, their load of drift filled up and completely covered the preglacial valleys, so that today we plow our fields and build our roads over those ravines, without suspecting the presence of the buried valleys over which we ride. Second, it is to the till that we owe the depth of the fertile soil which covers the bed rock over all of this region.

The influence of yet another ice sheet was felt in this region. The Iowan glacier, which succeeded the Illinoisan, did not extend so far south as the Macomb region. However, as this ice sheet melted, and before the surface of the drift became covered with vegetation, conditions favored the carrying and depositing of unusual quantities of dust by the wind. In this way the fine-grained

loess deposits that cover the glacial till in this region were laid down.

At some time during the glacial period, in the early part in Asia, and somewhat later in this country, man crossed the threshold of the temple of life which was being built through all the preceding ages. Since that time, so recent that over the surface of the latest drift a drainage system has scarcely become developed, man has grown from a fear into a knowledge of Nature and her laws, and through that knowledge into power, until he gained the dominant place which he holds today.

Since the retreat of the glacier, the changes of the earth's surface produced by the slow action of the natural forces have impressed upon this region the features with which you are all familiar. But these features are not the same as those the area will present during a future age.

We are introduced on the earth at this particular stage of creation, and because the changes take place so slowly that we can not note or measure their progress from day to day or from year to year we are prone to think that there is no change and that the present order of things is the same as it has been throughout the past. However, the Geology of our own region teaches us far different views of Nature and of life. Nature is always active, is ever changing. We are just now in the midst of one of God's creative days. At the present time man, too, has become a potent agency of change. With a fuller knowledge of Nature's laws, and an increased application of her forces his power is certain to increase more and more. To what he may accomplish or become before the end of the present geological age the highest stretch of the imagination would hesitate to limit or set the bounds.

PAPERS IN GEOGRAPHY

EXTRACT FROM THE REPORT OF THE CHAIRMAN

In addition to the papers in geography which are to appear in the Transactions of the Academy, the following two papers were presented in the section meeting.

"Major Climatic Controls of South America," by W. H. Haas, Northwestern University, Evanston.

"A Canadian Iron and Steel Center," by Harold B. Ward, Northwestern University, Evanston.

By a vote of the members in attendance, A. G. Tillman, Western Illinois State Teachers' College, Macomb, was elected chairman of the Geography Section for 1930.

W. H. HAAS, *Chairman.*

MUSEUM AIDS TO THE TEACHER OF GEOGRAPHY

FRANKLIN C. POTTER
Field Museum of Natural History, Chicago.

The movement among American museums to reach the public has been directed through the best possible medium—the schools. Realizing that the mere exposure to knowledge is not always fraught with the best success, the museums have presented this education in its most attractive setting. Not all of the activities have been centered on the child, it is true, for appeal is also made to the adult, but it is through the child, in the hope of extending the vast resources of the museum to the adult of tomorrow, that the campaign is being concentrated.

In this vast program the purveyor of geographical lore needs but to look to find his subject reached even to its widest applications. It is well to bear in mind that most of our larger institutions function as museums of *natural history*—the term *geography* being foreign to their curricula. Even so, their geographical resources, applications, and interrelationships are more vast than those of many distinctly geographical institutions. In fact, it would not be deviating widely from the truth to designate them as "Museums of Applied Geography."

As the exhibits are the special attraction, guide-lecture service exists for the purpose of disseminating information concerning them. The lecture tours vary from the most general to the very specific, the regular schedule embodying both kinds, but it is an exceptional audience that desires a very technical dissertation. Such tours are for the general public, and rarely do specialized groups utilize them, although industrial concerns in Chicago have been known to send employees to participate in tours that concern their businesses. But the special tours given by request on any sphere of a museum's activities and exhibits are the special prerogative of the teacher, for here he has an implement constructed especially for his needs.

The 1928 attendance figures for Field Museum of Chicago give an idea of the scope of this work. During that year 413 lecture tours were given to 17,392 school children from Chicago and its environs. None of these tours were standardized, each being

given on the subject requested. In the absence of statistical data it is difficult to draw satisfactory conclusions relating to the subject matter, but the experience of the writer has convinced him that the majority of such visits are sponsored by geography teachers and call for geographical subjects.

It may be well to add, also, a word concerning the personnel of the lecture divisions. Each lecturer must be familiar with the four departments of the museum (geology, botany, zoology, and anthropology), although each has specialized in some one department. Thus the training of the lecturer may influence his tour. Supposing a geography tour is requested on South America, if the lecturer be a botanist, it is not difficult to conjecture as to the department of the museum which he will utilize most fully in his portrayal of South American geography. The same holds true for the other three divisions, whereas a lecturer with geographical training will be more impartial and utilize each of the four departments to its best geographical advantage.

The Natural History Museum of the Chicago Academy of Science also gives lecture tours to visiting groups of school children, although geography is not presented as a differentiated subject. The Cleveland Museum of Natural History offers a series of graded lessons on natural history by resident teachers under the pay of the board of education. No definite tie-up is made with the school course of study, but the lessons can be, and often are, used by the teacher to give a background for certain phases of work in the regular school curriculum.

The Chicago Board of Education co-operates with the Field Museum to a considerable degree. Teachers, at their own discretion, may bring classes to the museum during school hours, and make museum studies an accredited part of the school work. For the grades (2 to 8, inclusive) there is a correlation program between the museum exhibits and the classroom studies in geography, history, science, and manual arts.

The museum libraries are also at the disposal of visitors. These well-stocked scientific libraries are among the best to be found anywhere, but only too rarely are they taken advantage of. Descriptive pamphlets relating to the exhibits are on sale at nominal prices within the reach of the school children. The pamphlets are written by the scientific staff, but are usually condensed and as non-technical as possible. Such pamphlets can be

successfully used for independent museum study or as a sequel to lecture tours.

Children's movies, with or without lectures, are an added drawing card at many institutions. The Natural History Museum of the Chicago Academy of Science and Field Museum have series of such Saturday morning programs. The subject matter in both institutions is related to natural history, but various phases of geography are well represented in most of the productions. The American Museum of Natural History in New York is one of a few to offer a series of movie lectures on definite subjects: natural history, early American history, geography, and industries. A geography series reads:

Africa
France And Her Neighbors
Child Life in Japan
Russia in Europe
South America
Mexico And Central America

One of the industrial series reads:

Life in the Far West
Our Waterways and Their Protection
The Conservation of Our Forests
Mining in the United States
Farming in the Middle West
Canada

Lecture courses are presented to the general public with no particular appeal to the schools. Students are welcome to them but are treated as part of the general adult public. These courses are popular and they do not delve very deeply into any particular science. For that very reason I believe that they are more valuable to geography than to any other science with the possible exception of anthropology.

The most important phase of the present-day museum program is not in the museum where the attractive exhibits are always free to the students, but it is the reaching out of the museum into the schools themselves. First let us consider the extension exhibits. The Cleveland Museum maintains loan exhibits in libraries throughout the city, in the schools of the suburbs where the museum's projects are being carried on, and in other schools, community centers, and such institutions where there are requests for loan material. The Field Museum, through the N. W. Harris

Public School Extension Department, in 1928 reached the public schools and such parochial schools, and organizations as the Y. M. C. A., social settlements, community clubs, and libraries to the number of 402. Of the more than 1,000 exhibits, three-fourths were in circulation among 371 public schools. There are 350 subjects, the more popular ones being duplicated from one to ten times. Two cases are delivered to each school at the beginning of the school year and changed every two weeks, so that each school receives 36 different cases in a school year. Only once in several years does the same case reach any one school, so a constant change and variety of subjects is maintained.

A few exhibits chosen at random are listed below to suggest the geographical value of the exhibits even though they are classified under the Natural History sciences.

Botany:

- Paper (various kinds)
- Dye-woods
- Coffee Plant and Product
- Cotton To Cotton Goods

Geology:

- Graphite (its uses)
- Useful Minerals
- Coal Mine
- Plate Glass and Mirror Making

Zoology:

- Bluejay
- Porcupine
- Eel
- Potato Beetle

With the possible exception of the zoological exhibits, most are geographical in their applications, and those pertaining to zoology, if nothing else, illustrate geographical distribution. Labels give in simple language the most important facts concerning the contents of the cases. Here then we have a medium for classroom study taken, as it were, right out of the museum.

More important than the cases are the extension lectures. The Raymond Lecture Division of Field Museum has a force of three lecturers giving extension lectures in the Chicago public schools. In the school year 1927-1928, 556 lectures were given to 209,290 children. These lectures, illustrated with slides, are given on those

subjects studied in the classroom which are displayed in museum exhibits. The list offered for presentation is as follows:

What We Owe to South America
Flax and Cotton
African Animals
Glimpses of Chinese Life
The Story of Coal and Iron
Food Fish of the World
Roman Home Life
Silk and Wool
Life of the Ancient Egyptians
Native Life of the Philippine Islands
Activities of Field Museum
North American Indians
North American Mammals
Mammals of the Chicago Area
Birds of the Chicago Area

These lectures stimulate an interest in the museum and ultimately bring the children to the museum in school groups or as individuals. The schools have their choice of two lectures with a possible return date for two additional lectures. Of the 530 lectures given in 1928, the leading choices were grouped as follows:

Indians	17%
Coal and Iron	14%
Birds	14%
South America	13%
Philippines	6%

And of the requests for the school year of 1928-1929, the leaders were as follows:

South America	12%
China	11%
Indians	8%
Coal and Iron	8%
Fish	7%
Flax and Cotton	7%

Note that in each instance a majority of the leaders are those lectures most closely allied with geography. From talks with a limited number of principals, the writer has ascertained that more than one-half either choose the lectures from a geographical viewpoint or allow their geography teachers to make the selections.

These lectures are adapted for the particular grades, usually geography classes, studying the lecture topic. The extension lectures constitute one of the more important of the geography teachers' assets, at least of the teachers in Chicago.

Right at our very doors, in the larger cities at least, are the second-best geographical laboratories, second only to the actual regions themselves. And these museum laboratories offer a wealth of material; in fact, they invade the schools to deliver it. Has the geography teacher exerted as much effort in his search for this information? A corollary of the above might also be stated. Not only can geography get a great deal from the modern museum, but it should contribute to the museum more than it does. The museum organizations should realize more the value of geography, for no other science can or does have the breadth of view to weave this thesaurus of material into a unit whole. It remains for the geographer to take the many interrelated exhibits and make them with word pictures into living things for the museum visitor.

It may be well to close with a mere truism: Not only do we need to utilize the museum more in our study of geography, but the thousands of daily visitors need also the geographer to interpret for them the varied exhibits. At least a majority of those who come to the museums are not there from idle curiosity, as is attested by the attention given to the presentations of the guide-lecturers. The public wants to know, and it should be given not a partial but a comprehensive view.

THE BRITISH COAL MINING INDUSTRY

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Prior to the World War favorable environmental conditions made coal mining one of the more prosperous industries in the United Kingdom. Besides furnishing outward cargoes for vessels that returned with food supplies and raw materials for manufacture, coal is a valuable item in the total export trade of Britain. Owing to the increased coal production of the world, the changes in the centers of production, the political issues, and the use of alternative sources of power, the export of this commodity from Britain has fallen, and low prices have made it unprofitable to work many mines owing to high production costs. In addition, the industrial depression at home has materially decreased the demand for coal in Britain itself. These unfavorable economic conditions have largely offset the geographic advantages of the past and are mainly responsible for the present distressed condition of the British coal industry. Only by complete reorganization in methods of production and marketing can this industry regain its former importance.

TABLE I—BRITISH COAL PRODUCTION BY DISTRICTS.*

Districts	1913	1925
Pennine Group—		
Northumberland and Durham	56,352,000	43,448,000
Cumberland and Westmoreland	2,321,000	1,986,000
Lancashire and Cheshire	24,629,000	17,422,000
North Stafford	12,929,000	11,524,000
York, Derby and Nottingham	80,706,000	75,132,000
Midland fields	13,500,000†	10,074,000†
South Wales and Monmouth	56,830 000	44,630,000
Scotch Group—		
Ayrshire	4,689,000	4,120,000
Clyde Basin	23,313,000	16,994,000
Fife, Clackmannan and Lothian	14,454,000	11,914,000
Total—England and Wales	244,891,000	210,148,000
Total—Scotland	42,456,000	33,028,000

* From U. K. Statistical Abstract, 1927, pp. 230-1.
† Estimated.

FIG. 1. Map showing coal fields of Great Britain. (*Courtesy of the Manchester Guardian Weekly.*)

DISTRIBUTION AND CHARACTERISTICS OF BRITISH COAL FIELDS

An examination of Figure 1 will show that the coal fields of Great Britain may be divided into three main groups:

A. Fields lying on or near the flanks of the Pennine Mountains.

B. Fields located adjacent to the coast of South Wales and Monmouth.

C. Fields of the Scottish central lowlands.

The comparative significance of these main groups and of the chief producing areas within each may be seen in Table I.

A. THE PENNINE GROUP

The Pennine group comprises five fields: (1) Northumberland; (2) Cumberland; (3) York, Derby, and Nottingham; (4) Lancashire and Cheshire; and (5) Midland fields.

Geologically these fields are closely interrelated. The oldest formation in the region is mountain limestone. This was overlaid by successive deposits of clays, coal, and magnesian limestone, in almost horizontal beds. Erosion, following the upfolding which formed the Pennine mountain system, removed the more recent deposits from the crest of the upfold and exposed in many places the mountain limestone. Thus, the beds of coal which originally were continuous across much of the area were divided into eastern and western groups. Subsequent deposition has effectively preserved the coal measures that outcrop on the flanks of the mountains.

(1) Northumberland and Durham Coal Field. This covers an area of 700 square miles. It extends along the coast for about 50 miles and inland to a maximum distance of 30 miles. There is an estimated reserve of 10,000 million tons. The seams, fairly regular in character and averaging from three to five feet in thickness, outcrop on the western flank, dip somewhat steeply towards the east, and continue under the sea. As shown in Figure 2, most of the largest mines lie near the coast and are of considerable depth. The mouths of the rivers Tyne, Wear, and Tees form nearby commodious harbors through which 70 per cent of the output is shipped. Blyth, Newcastle, Sunderland, and Middlesbrough handle the bulk of this trade. Deep water has been provided to permit the use of large ocean boats and modern loading machinery

has been installed to facilitate rapid loading (Figure 3). This field normally provides about one-third of the total export of the country.

The abundant supplies of coal, together with the accessibility of the area for the receipt of raw materials and for the distribution

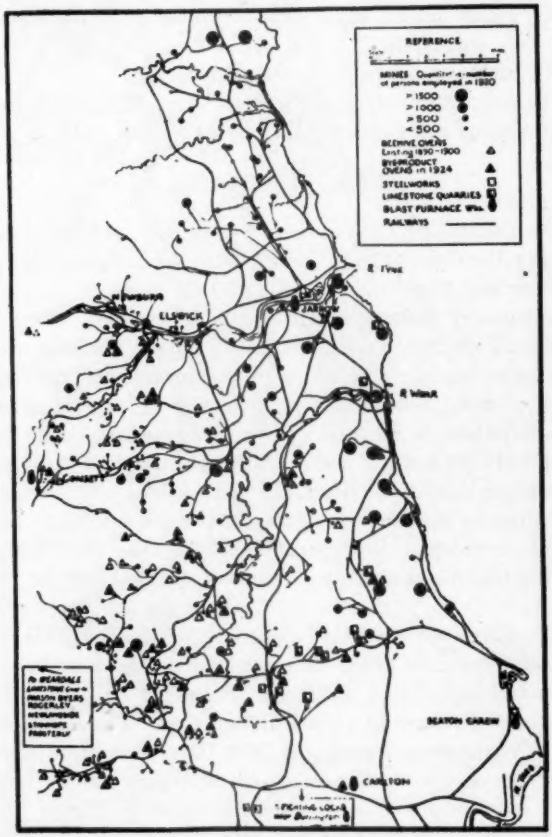

FIG. 2. Most of the large mines in Northumberland and Durham are located near the coast. (*Courtesy of Ll. Rodwell Jones.*)

of manufactured goods by sea and land, are the bases for the great industrialization of the region which provides employment for a dense urban population. Agriculture is of minor importance. Many of the smaller urban centers are almost entirely dependent upon the mining industry.

(2) The Cumberland Coal Fields. This comprises a narrow belt along the coast. The field is definitely limited on the east by pre-carboniferous rocks, but it extends westward under the sea and northward under Solway Firth where it becomes accessible again in southwestern Scotland. The estimated reserve of accessible coal in this area is 3,000,000,000 tons. The chief producing districts are around Whitehaven, Workington, and Maryport where artificial harbors have been constructed to facilitate coal shipments.

The lack of natural harbors, the rugged character of the hinterland, and the very considerable faulting that occurs in the coal measures are the more significant disadvantages.

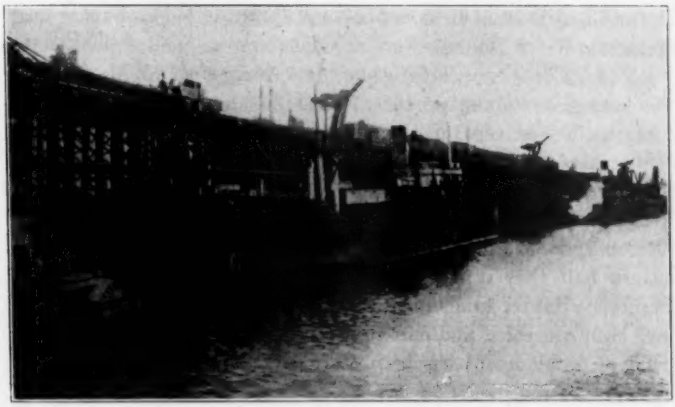

FIG. 3. One of the coal docks at Newcastle capable of handling 23,000 tons per day.

Except for its deposits of hematite iron ore which form the basis for an important iron and steel industry at Barrow, the area has little of economic significance. The population (approximately 1,000,000) is almost exclusively dependent upon the resources of coal and iron.

(3) Lancashire and Cheshire Coal Field. This field is divided into two parts. The northern area around Burnley and Blackburn is separated from the southern portion, which extends from St. Helens to Stockport, by an area of moorland, the Rosendale Hills, composed of millstone grit from which the coal has been eroded. The Pennines limit this field on the east, while extensive faulting renders the coal inaccessible to the west and south.

The location of this field relatively near to tidewater led early to the building of canals to facilitate the movement of coal to the Mersey. The chief producing districts are in the neighborhood of Bury, Bolton, and Oldham. Most of this coal is used in the local industries of which cotton manufacturing is by far the most important.

A southern extension of the Lancashire field occurs in North Staffordshire. Actually it belongs to the Midland group, but economically it is closely associated with the Mersey by way of the Weaver Canal. Practically all the coal produced is used locally, chiefly in the pottery industry. Similarly, the North Wales coalfield is a continuation of that of North Stafford. The production is small and most of it is shipped out by rail either as bunker coal or to supply the iron smelters at Carnarvon.

(4) The York, Nottingham, and Derby Coal Field. This is the largest and most productive coal field in Great Britain and contains 30 per cent of the total reserves of the country. The field covers an area of approximately 2,400 square miles, the boundaries being marked by lines joining Bradford, Goole, Derby, and Grantham. In the western half of the field the coal measures outcrop and have been worked for a considerable period. In the eastern half they dip down under a thick mantle of Magnesian limestone, Bunter sandstone, and Keuper marl, under which they have been concealed and effectively preserved. In recent years the trend of development has been eastward, and at the present time little production occurs on the western edge. The most productive and exploited area occurs down the center of the field near the eastern edge of the exposed coal measures. There the seams vary between 4 and 9 feet in thickness and consist of very high grade coal. At the present time 35 per cent of the total output of the country is mined in this field.

Owing to its inland location exports from the area are smaller and rail hauls longer than in the coastal fields. Consequently, the railroads, and to a smaller degree, canals, play a more important part in the distribution than elsewhere. Normally 20 per cent of the total production is shipped out through Hull, and 10 per cent through Liverpool. Of the remainder, the greater part is used in the local blast furnaces, steel mills, woolen mills, and other manufacturing industries which have grown up in this area and in the neighboring Midland industrial districts. In addition, the dense population creates a large demand for domestic coal.

As in the Lancashire-Cheshire districts large scale manufacturing industries are the dominant activities. Nevertheless, dairying and other types of specialized agriculture are significant, and provide employment for considerable numbers.

(5) The Midland Coal Fields. This group of four small detached coal fields occupies a roughly triangular shaped area in the western portion of the Midland Plain. They comprise the South Stafford, Warwick, Leicester, and Shrewsbury fields. The area is covered with New Red Sandstone which has weathered into a deep fertile soil. Consequently, except in those districts where the coal is sufficiently near the surface to be worked profitably, the area is agricultural in character and less dependent on coal mining than is the case in many of the other mining areas. On the South Staffordshire field intense industrial activity has developed based on local or imported raw materials. The coal consists of good grade bituminous varieties suitable for industrial purposes, and most of the output is consumed locally or in the surrounding areas. Excellent rail and good canal facilities are available.

B. The South Wales Coal Field

The South Wales field covers an area of 1000 square miles and extends from St. Brides Bay on the west to Monmouth in the East, a distance of 90 miles. This is the most important coal field of Britain.

Surface conditions throughout the region are rugged, and in many places the upland extends to the coast breaking the continuity of the rather narrow coastal plain. The rapidly flowing Usk, Taff, Tawe, Neath, and their tributaries have cut deeply entrenched valleys along the sides of which the coal seams outcrop (Figure 4). These valleys and the intervening barren highlands make east-west communications difficult. Nearly all the railroads are built along the valleys, sometimes on each side of the stream, but down grades to the coast facilitate the shipment of the coal. Many of the valleys terminate near good harbors, around which the great metallurgical industries and coal docks are located (Figure 5). Owing to favorable shipping conditions most of the coal is moved out of the area by water rather than by rail. Normally 75 per cent of the total output is exported. Cardiff handles more than 50 per cent of the trade; Newport, Swansea, and Port Talbot, the bulk of the remainder. The coal-handling

FIG. 4. A typical South Wales valley. The railroad may be seen on the right bank of the river.

FIG. 5. An airplane view of Cardiff harbor. The coal docks may be seen on the left.

facilities of these ports have been brought up-to-date, and adequate provision has been made for handling a large tonnage expeditiously (Figure 6). Most of the mining as well as many manufacturing industries are carried on at the present time in the valleys. The towns are usually only long rows of houses, built close to the hillsides where the sun seldom reaches them. Over-crowding and cheerless conditions prevail throughout most of the mining districts. Sheep raising on the uniformly infertile uplands is the only form of agricultural activity.

The main coal field occupies a synclinal basin in which the seams dip somewhat steeply, especially on the south. The coal measures contain from twelve to forty seams with an aggregate thickness of from 21-120 feet of coal. Workable seams extend to depths of more than 4000 feet. Since most of the outcrops have

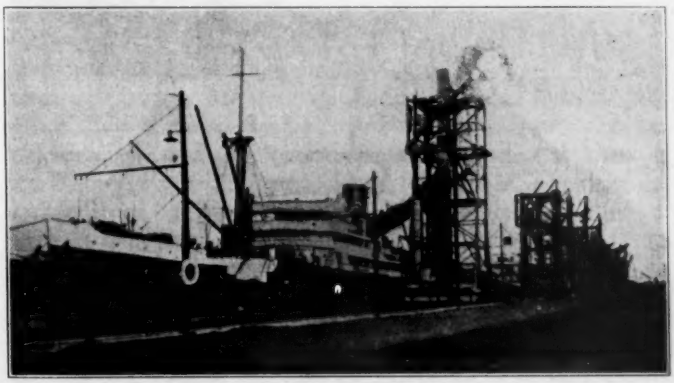

FIG. 6. One of the coal docks at Cardiff, showing the loading towers and chutes into which the coal is dumped from the cars.

been exhausted, shaft mining at considerable depths is now the chief mining method employed. This is true of most of the British fields. Several varieties of very high-grade coal, ranging from bituminous to anthracite, are produced and their high quality gave them a veritable monopoly in the markets where they were sold. In general, the coal becomes more anthracitic in character from east to west, bituminous coal in the east, smokeless steam coal in the central parts, and anthracite in the west (Figure 7). Approximately 30 per cent of the reserves are bituminous, 47 per cent steam coal, and 23 per cent anthracite. These are estimated to amount to 30,000 million tons.

Geologically, the strata are more disturbed than those of any other British coal field. Faulting, loose jointing, and rotten roofs make mining more hazardous than usual. The seams, particularly in the anthracite districts, are irregular and their continuity is interrupted. The dry, fiery character of the coal dust is a serious handicap. Consequently, large scale operations are difficult and mining is more costly than in other parts of Britain.

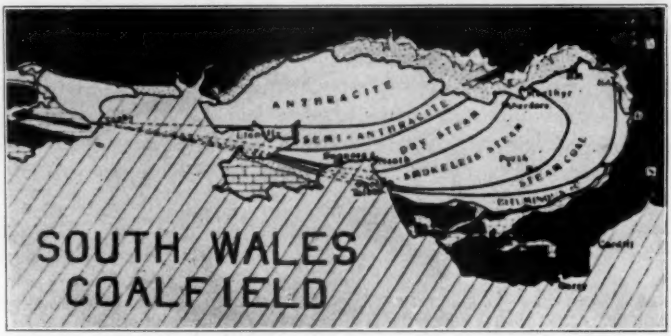

FIG. 7. A simplified diagram showing the varied character of the coal in the South Wales field.

C. THE SCOTTISH COAL FIELDS

The coal of Scotland is confined practically to the Central Lowland. Formerly, carboniferous rocks, covered by volcanic and glacial deposits, extended throughout the region. Erosion, subsequent to the formation of the rift valley, removed most of these carboniferous rocks containing the best coal seams. The existing deposits occupy three basin-like areas within which the coal has been preserved.

The most westerly of these deposits is known as the Ayr Basin. Most of the output, some 4,000,000 tons annually, is exported from Androssan, Ayr, Irvin, and Troon to Northern Ireland, chiefly to Belfast.

The second and most important deposits, since it supplies half the total Scotch production, extends along the Clyde Valley for some twenty miles above Glasgow and northeastward under the Forth to Clackmannan. This coal, eminently suitable for metallurgical purposes and for gas production, lies near the surface and can be mined easily. The effectiveness of communication by sea, river, canal, and railroad, the high grade of the coal, together

with local and imported supplies of raw materials, have favored intense industrial development there.

The eastern deposit, in the Fifeshire Basin, extending under the Forth from Midlothian to Fifeshire, and separated from the Lanark Basin by a ridge of volcanic and older rocks, has been worked less extensively than either of the others. Since it contains almost half the total Scottish reserve, a fuller development may be expected as the Lanark supply is depleted. The total Scotch reserves amount to some 20,000 million tons.

In addition to great diversity in manufacturing, agriculture is one of the basic activities of the region. Rich soils derived from volcanic, glacial, and other sources, a not unfavorable climate, and a dense urban population which constitutes a large local market, have been important factors in its development.

CONDITIONS FAVORING COAL PRODUCTION

British coal fields are located advantageously in respect to their utilization. The enormous demand for coal created by the great industrial development of the country, which has taken place either on or near the coal fields themselves, has stimulated mining. Excellent railroad transportation has been provided, so that coal can be distributed readily to any part of the country. Since all the coal fields are either adjacent to, or within easy reach of, tidewater and good harbors which have been equipped to handle coal in bulk, there is a large movement of coal by water. The proximity of Britian to the great industrial and densely populated areas of Western Europe, the abundant and uniformly high grade of the coal, the world-wide British commercial interests, and a large merchant marine, have been important factors in the development of a large export trade in coal.

At present these advantages are largely offset by an increasing cost of mining resulting from deeper mines and thinner seams, by the increase in railroad rates in recent years, and by the competition of more recently developed mining regions in continental Europe where cost of production is lower.

Great Britain has large supplies of high-grade coal suited for the many purposes of a highly industrialized country. The character of the coal varies both in the different areas as well as within the individual fields, but it is uniformly high in quality. In South Wales smokeless or anthracitic varieties predominate. South-

west Durham is famous for its high-grade coking coal. The cannel coals of Scotland are excellent gas coals.

The estimated reserves of workable coal in Great Britain are 180,000,000,000 tons, or sufficient to last several hundred years at the present rate of production. Approximately 60 per cent of the coal is in England, the principal reserves being in the Pennine and South Wales regions[1].

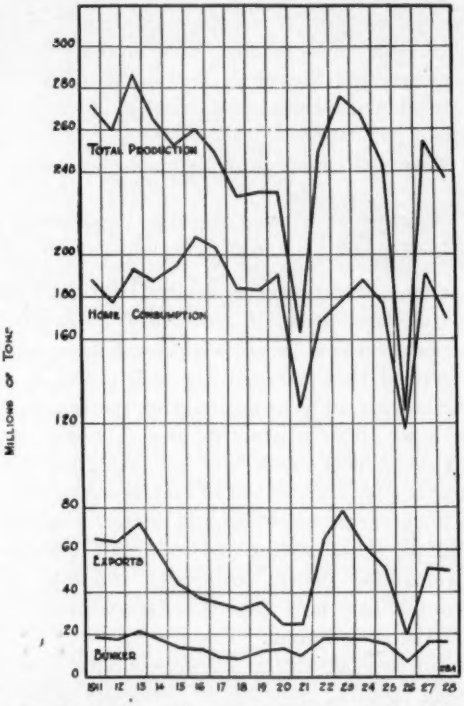

FIG. 8. Graphs showing the production and utilization of coal in Great Britain from 1911 to 1928, based on Board of Trade data. Imports of 20,000,000 tons in 1926 account for the apparent discrepancy in the total production and consumption for that year.

TRENDS IN PRODUCTION

Prior to 1914, the world production of coal was increasing at the rate of 30 million tons per year, and this had been a constant factor in the organization of the industry. The steady advance was interrupted only by strikes and temporary depressions in business.

[1] Sargent, A. J.; *Coal in International Trade*, pp. 16-17.

and the resumption of normal conditions soon made good any losses which had occurred in the meantime. As a result, more miners were recruited year by year, workings were extended, new mines were opened, and facilities for production were increased. In all the great coal-producing countries productive capacity was being increased constantly to take care of the expected increase in demand.

In Great Britain the peak was reached in 1913 with a total of 286,000,000 tons (Figure 8). From that time there has been a decline. In 1928, production was only 237,000,000 tons, a decrease of 49,000,000 tons. About four-fifths of this difference was due to

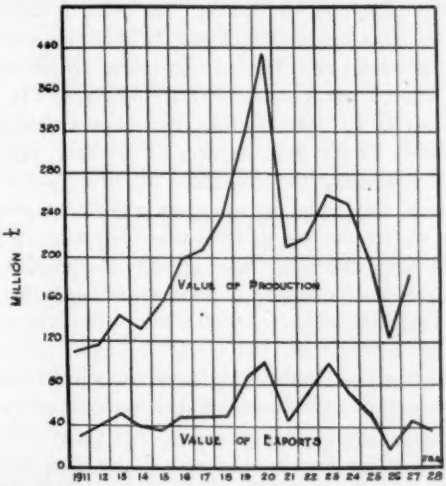

FIG. 9. Graphs showing the trend in the value of coal between 1911 and 1928, based on Board of Trade data. It is estimated that costs of production have trebled since 1913.

the loss of exports. Except for 1926, when the mines were closed for seven months because of a national stoppage, the year 1928 can be considered the worst on record and probably will prove to be the critical turning point in the organization of the industry. The depressed condition of British manufacturing industries as a whole resulted in a decreased demand for coal for home consumption. This is particularly true in the case of the heavy industries, especially iron and steel, all of which are suffering as a result of foreign competition and loss of markets due to the dislocation of trade occasioned by the war.

Owing to the low price of coal (Figure 9) and high operating costs resulting from irregular working, it is estimated that since the end of 1926 the coal industry has been carried on at a loss of more than $70,000,000. Table I shows the production of coal in Great Britain by districts for 1913 and 1925. From this it will be seen where the chief decline in output occurred. Conditions in 1928 show still greater decreases compared with those of 1913, but complete data for individual districts for 1928 are not available.

UTILIZATION OF BRITISH COAL

A comparison of the graphs in Figure 8 will show the relation between production and utilization. In 1913, approximately 67 per cent of the total production of 286,000,000 tons was utilized in Britain for industrial and domestic purposes, 25 per cent was exported, and about 7 per cent was used in bunkering. In 1928, with production only at 237,000,000 tons, home consumption took care of approximately 72 per cent, exports 21 per cent, and bunkers 7 per cent. On comparing the utilization of the output in these two years it is seen that home consumption was 38,000,000 tons and exports were 23,000,000 less in 1928 than they were in 1913. The bunker trade remained fairly normal. It is apparent that the prosperity of the coal industry is dependent largely on foreign as well as home markets.

TABLE II—BRITISH COAL EXPORTS BY KINDS, INCLUDING OTHER FUELS.*

Kind of fuel	1913	1925	1928
Coal—	Long tons	Long tons	Long tons
Anthracite	2,976,000	3,014,000	3,157,000
Steam coal	53,619,000	38,281,000	34,866,000
Gas coal	11,528,000	6,820,000	6,518,000
Household coal	1,770,000	1,710,000	1,757,000
Other coal	3,507,000	2,992,000	3,757,000
Total tonnage	73,400,000	50,817,000	50,055,000
Total value (£)	52,000,000	50,000,000	39,000,000
Coal shipped for use of steamers engaged in foreign trades	21,024,000	16,436,000	16,729,000
Coke	1,235,000	2,112,000	2,596,000
Manufactured fuel	2,053,000	1,160,000	1,032,000
Total	24,312,000	19,708,000	20,357,000

* British Official Trade Returns, 1913, 1925, 1928.

The nature of the export trade is shown in Table II. Under normal conditions prevailing before 1914, coal provided one-tenth of British exports in value and about four-fifths of them in volume. It furnished an outward bulk cargo for a large amount of shipping which returned to British ports with supplies of foodstuffs and raw materials so necessary to Britain. As a result, freight rates were considerably lower than they would have been otherwise, and this was reflected in the price of imported commodities. Owing to Britain's world-wide trade and her large merchant marine, it is essential that cheap bunkering coal be available along the lanes of ocean commerce. The transportation of this coal, likewise, provides outward cargoes to all parts of the world, and the returning vessels normally experience little difficulty in picking up a bulk cargo of some commodity needed in England. Foreign vessels also are attracted to British ports by cheap bunker coal and constitute an outlet for very considerable tonnage. An examination of Figure 8 will show that fluctuations in the bunker trade have been slight even under present conditions.

TRENDS IN EXPORT TRADE

The chief two European coal-producing countries in 1913 naturally provided the greater part of the surplus for export. The chief deficit countries were France, Austria, Hungary, Italy, Holland, Denmark, Belgium, Spain, and Scandinavia. Of these, Italy was supplied by sea, Austria and Holland by land, and Belgium and France by both land and sea. Of the two surplus regions, Germany dominated the land trade of Central Europe, owing to the strategic location of her producing areas in Westphalia and Silesia. Britain monopolized the Mediterranean markets. In the countries on the western margin of the continent there was competition between the two sources of supply. Figure 8 shows the trend in British exports from 1911-1928. In drawing conclusions from this graph it should be borne in mind (1) that war conditions led to a restriction of exports from 1914-1919, (2) that conditions in Germany in 1923 stimulated British exports, and (3) that the seven-month British stoppage in 1926 was responsible for the small export of that year, and for a very considerable import.

The year 1925 may be taken as representing post-war trading conditions in making comparisons. Table III shows the distribution of British coal exports for the years 1913, 1925, and 1928. A comparison of the overseas trade in 1913 and in 1928 shows in

which of the markets the falling off has been most serious. Actually European countries are consuming more coal than in 1913, but Great Britain is not supplying these increased needs. She is the only country in Europe whose production has decreased, and her situation is rendered all the more acute because her capacity to produce is much greater than it was in 1913. The decreased output is due to the loss of a relatively large part of her share in the world's trade. French consumption has increased by 6,000,000 tons, but in 1928 imports from Great Britain were 2,000,000 tons below normal. In 1913, England supplied 9,000,000 tons to Italy. In 1928, only 6,600,000 tons were shipped, yet the consumption of coal in Italy had increased from 10,000,000 tons to 15,000,000 tons. Political considerations rather than geographic conditions are responsible largely for these reductions. Owing to the high prices of 1921 and 1922, which resulted from a shortage in supply (Figure 9), European countries were encouraged to economize in the use of coal, and to increase the productive capacity of their own mines. Some, especially Poland, have begun to build up an

TABLE III—DISTRIBUTION OF BRITISH COAL EXPORTS.*

Country	1913	1925	1928
	Long tons	Long tons	Long tons
France	12,776,000	10,235,000	9,065,000
Italy	9,647,000	6,811,000	6,622,000
Germany	8,952,000	4,165,000	5,368,000
Denmark	3,034,000	2,783,000	1,731,000
Sweden	4,563,000	2,727,000	1,540,000
Belgium	2,031,000	2,486,000	2,260,000
Irish Free State		2,244,000	2,423,000
Spain	1,749,000	1,756,000	1,867,000
Norway	1,509,000	1,750,000	1,117,000
Holland	1,397,000	1,527,000	2,434,000
Portugal	871,000	851,000	961,000
Greece	438,000	610,000	637,000
Finland		521,000	370,000
Russia	5,998,000	64,000	24,000
Total to Europe	62,510,000	39,194,000	36,985,000
Total to South America	3,284,000	4,214,000	4,776,000
Total to other countries	7,606,000	7,409,000	8,294,000
Total exports	73,400,000	50,817,000	50,055,000
Total production	287,000,000	243,000,000	237,000,000

* British Official Trade Returns, 1913, 1925, 1928.

export trade. All those with coal resources have put their mines in order and materially increased their production. The effects of these improvements are making themselves felt to Britain's disadvantage. German reparations in coal to France, Belgium, and Italy have helped to reduce British exports to those countries. Special rebates on government railroads enable some of the continental producers to compete successfully with British water-borne coal. As a result of this combination of circumstances, British exports in 1928 were 23,000,000 tons less than in 1913. The Bristol Channel and Northeastern ports suffered most in this great contraction in the export trade.

The coal trade has been affected by a variety of other factors, chief of which are fuel economy and the competition of other sources of energy—oil, gas, and water-power. These have affected both home and foreign consumption. High prices and actual shortage during the world war drew the attention of consumers to the need for increased fuel economy. The results of these efforts are now making themselves felt after the high prices and deficiency conditions have disappeared. Within the last few years there has been a 25 per cent increase in efficiency in the consumption of coal. This has been particularly noticeable in the electrical utilities and in the iron and steel industry. In 1906, a unit of electricity necessitated the consumption of 18.5 lbs. of coal. In 1926, the average consumption was 2.53 lbs. per unit. At the present time electric utilities in Britain utilize 8,000,000 tons of coal a year, while in 1906 the same output would have necessitated 50,000,000 tons. One of the chief means by which this has been accomplished has been the replacement of small isolated plants by large central units.

Present developments point to further increases in coal efficiency. The production of gas per ton of coal used has been materially increased. Improved boilers and equipment have enabled the railroads to increase the power derived from each ton of coal by 22 per cent. The consumption of coke in the iron and steel industry has decreased by 15 per cent in 10 years. Improved coking processes, the utilization of by-product gases and waste heat, the development of continuous processes, and up-to-date equipment have made this economy possible.

The use of hydro-electric power is being rapidly extended wherever environmental conditions permit, and particularly in those countries of Europe that have no coal resources or only in-

adequate supplies. In 1925, the amount of water power actually used in Europe was equivalent to 28,000,000 tons of coal, or about one-ninth the British production of that year. Many British markets are affected by this substitute for coal. South America has increased her developed waterpower by 59 per cent and Africa by 27 per cent. Norway, Sweden, and Italy have made notable developments in this respect.

Another significant factor affecting the British coal trade, particularly that of South Wales, has been the increased use of oil for ship propulsion. Each oil-burning warship represents a loss to the coal industry of about 1,500,000 tons per year, and each oil-burning liner a loss equivalent to the total output of an average mine.[1]

LABOR AND SOCIAL ASPECTS OF DEPRESSION

In 1913, when the output was 287,000,000 tons, upwards of 1,100,000 men were employed in the industry. By 1925, production had fallen to 243,000,000 tons but the number of wage earners was still in excess of 1,100,000. In 1928, the number employed dropped to 900,000 men, a decrease of 60,000 compared with 1927. Since 1925, some 200,000 skilled and semi-skilled coal miners have been thrown out of work, and most of those remaining in employment have been on part time.

Lack of demand led to the closing of 502 mines in 1927. This threw 56,000 miners out of work. In 1928, still more were closed, and there was a further increase in unemployment. The trends of production and numbers employed during 1928 for Great Britain as a whole and for South Wales are shown in Figures 10 and 11. The graphs show clearly the marked decrease in employment. They also show the effect which the installation of improved equipment is having upon production. The output per man is being increased, with a consequent reduction in costs.

One of the outstanding social problems has to do with the surplus mining population. It is generally recognized that the industry is overmanned to the extent of 200,000 men. The seriousness of this situation may be seen more clearly when it is realized that in many cases large towns and villages are entirely dependent upon local mines around which they have grown up. The closing down of many of these mines has thrown almost the entire local population out of work. At one time, with a population of 10,000, Brynmawr had only 400 employed persons, none of whom were

miners. At West Auckland, in Durham, 6,000 people were dependent upon two collieries. One has been closed for five years, the other for three years. Neither will open again. Nine-tenths of the 1,400 homes are poverty-stricken. In normal times these were prosperous communities, many of the miners owning their own homes which had been purchased through local co-operative societies.

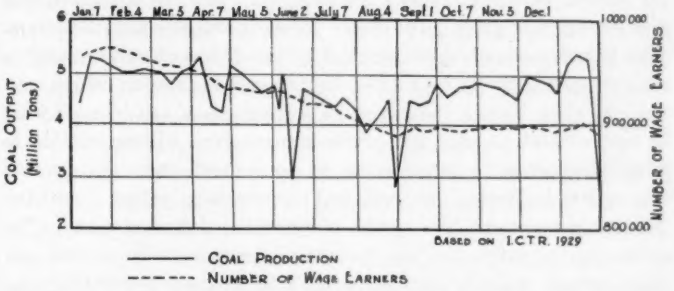

FIG. 10. Trends in production and numbers employed for 1928. The graphs are based on weekly totals.

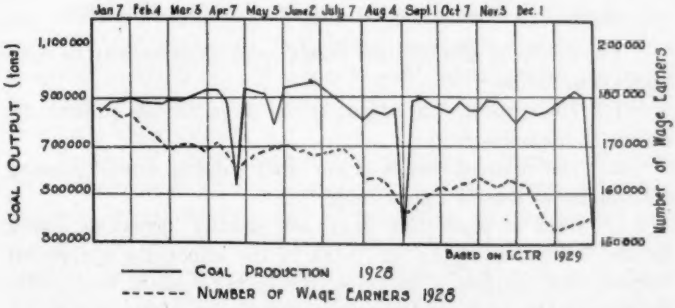

FIG. 11. Trends in production and numbers employed in the South Wales coal field in 1928, based on weekly totals.

There are many such cases where mines supporting similar communities have been closed down for as much as four years. Many of these mines will never reopen. The question of what to do for these communities presents a very serious problem. To move the people to other districts would intensify employment problems there. In many districts miners have been on half time or less for several years and their condition is tragic. Government relief barely enables the unemployed and their dependents to exist.

Most miners have long since exhausted their benefits under the National Unemployment Insurance scheme which provided unemployment pay for a period of months, and towards which the miner pays a weekly contribution when employed.

Relief in almost every form has been, and in many communities still is, necessary to keep these people from actually starving. The Miners Union has long since exhausted its funds. As harvest hands in Canada, the miners were hardly a success, and the scheme has given little relief to the unemployment situation. The transference of these people to other forms of employment is all the more difficult because of the general depression which prevails in most British industries. The Dominions are in need only of agriculturalists, and few of the miners seem willing or able to adapt themselves to farm work. It is evident that the present stagnation is having an evil and far-reaching effect upon the younger generation. The system of relief has degraded many. The older miners have in the past few years been reduced to poverty and hopelessness. Only by increasing sales by at least 50,000,000 tons per year can the present mining population be employed.

BRITAIN'S COAL PROBLEM AND ITS POSSIBLE SOLUTION

The problems affecting the British coal industry may be summarized as follows:

1. The capacity for output is too large for the present demands of the industry.
2. The value of coal is so low that mining under existing conditions has become unprofitable.
3. Costs of production have been steadily increasing, owing to the increasing depth of many of the mines, the antiquated methods and equipment employed, the higher costs of transportation in recent years, and the irregular working of most of the mines.
4. Too great a number of competing units under existing trade conditions has resulted in uneconomic marketing.

Any schemes for the solution of the present difficulties must take these factors into consideration. In view of the fact that Britain's productive capacity is equal to 300,000,000 tons per year, it is clear that either the national output must be regulated to meet the market demands or the export trade must be stimulated and expanded to take care of the surplus. Owing to the excess of coal available, not only in England but also in Germany and Poland,

values have fallen below the level at which many British producers can operate satisfactorily. Therefore, mining costs must be reduced to a point at which Britain can compete on favorable terms with continental producers. While Britain is still the chief source of supply for over-seas requirements, she is faced with far keener competition than formerly. Germany has increased her exportable surplus. Poland has become an important factor in the international coal trade. Both countries have improved their facilities for coal production and shipment. Both give preferential railroad rates on coal. Consequently, British coal operators are faced with the problem of reorganizing their units and the marketing aspects of their industry, and of reducing their costs by the elimination of wasteful and antiquated methods of production.

At the present time considerable progress has been made in respect to consolidation with the view of eliminating the less productive mines and concentrating upon those where conditions favor a larger output at lower cost. In the anthracite area 85 per cent of the production is now under one control, The Amalgamated Anthracite Collieries, Ltd. This organization includes some 200 mines, employing 136,000 workers. The better mines are being improved, equipment brought up-to-date, and the tonnage per man per shift increased. One selling organization eliminates uneconomic competition, and orders are distributed among the mines to better advantage. As a result conditions look more hopeful in this part of the country.

Under the "Five Counties Scheme" the collieries of Yorkshire, Derbyshire, Nottinghamshire, Cheshire, Cannock Chase, Leicester, North Stafford and Warwickshire, with an annual output of about 100,000,000 tons, are affiliated in what is known as the Central Collieries Commercial Association. The organization aims to regulate the output of each colliery by allotting a definite quota to all, subject to revision each month. A levy based on output is made on all members to subsidize the export trade. Export bureaus and port committees of colliery representatives are maintained at Liverpool and Hull to supply regular information as to the state of the export market. These bureaus conduct the export business at a fixed remuneration. The internal sales of this group are being handled in a similar manner. It is expected that this concentration of the sales organization will effect considerable economy in operations, eliminate uneconomic competition, and facilitate the development and extension of the export trade. This

marketing scheme is comparable with that set up by the great continental producers, particularly the Rhenish Westphalian Coal Syndicate, which has successfully stabilized prices and regulated mining operations in Germany. Similarly, sales organizations in Poland are in a few hands, effectively restricting inland competition, and assisting the development of an export trade. Belgium and France are adopting the same practices.

Scottish operators have instituted a similar scheme with the same general objectives. Output has been restricted and competition has been reduced. By voluntary agreement some of the least effective mines have been closed and their owners compensated out of a levy raised for the purpose.

These schemes for centralized control have met with some success. Over production has been checked, more up-to-date mining methods are being employed, and the opening up of new mines has been restricted. By reducing taxation temporarily, the Government has helped to reduce the f. o. b. prices on export coal. It is hoped that eventually a national marketing scheme will be developed whereby (1) uneconomic inter-district competition will be avoided in the inland as well as the export trade, (2) the lost export trade will be recovered, and (3) new markets will be found in which British coal can be marketed profitably.

PATTERN OF LAND OCCUPANCY IN THE MEXICAN LAGUNA DISTRICT

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University of Chicago.

The purpose of this paper is to present the results of one day of field study last summer. The field work illustrates a method in which details about a small area are included as an important part of reconnaissance in a large area; and the interpretation illustrates a point of view focussing on the pattern of land occupancy as a central feature of geographic analysis.

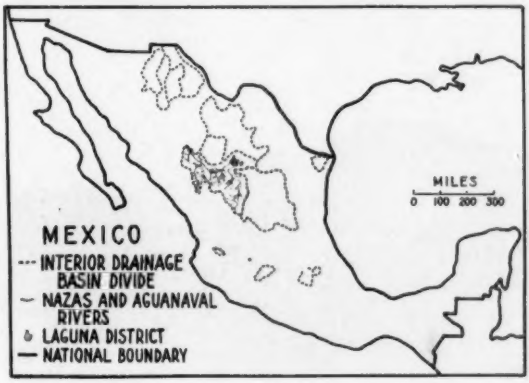

FIG. 1.

Most of northern Mexico is too arid for agriculture without irrigation. The places that are not too arid are too rugged, being only the upper slopes of the higher mountains. Therefore, the best agricultural possibilities are in the utilization of mountain rainfall to irrigate plains.

An indication of aridity is seen in extensive areas of interior drainage (Figure 1). All of these areas have some rainfall and some streams within them, but most of them consist of desert basins and low dry mountains with little rainfall and few streams. The one containing the greatest area of high mountains is the basin of the Nazas and Aguanaval Rivers. Seasonal rainfall in the Sierra Madre Occidental is collected by a network of headwater

streams and poured down the two river valleys and out of the mountains into the broad basin of the Laguna. The amount of water delivered at the mouth of the two canyons is greater than that at any other place in any of the interior basins. This is the natural basis for the greatest irrigation district in the Northern Plateau.

Where the rivers break from the mountains, canals lead off from them to distribute water to fields laid out on the desert plain (Figures 2 and 3). The pattern is simple and distinct: the run-off from thirty thousand square miles of mountains, accumulated and carried down by two rivers, distributed by a network of canals over the plain.

FIG. 2. Nazas River and irrigation canal headgate. Laguna District downstream to the right, mountains upstream to the left.

The features of the pattern include not only the canals ramifying from the rivers, but also the fields which they water and which produce crops, and property divisions with their water rights laid out for systematic development of agriculture (Figure 4). The greater subdivision of property in the area of irrigation is evident. The pattern includes also a network of transportation lines supplying the needs and carrying out the products of the fields, villages to house the workers, and commercial centers to serve the area (Figure 5). The chief city is Torreon at the point where the rivers leave the mountains. These features and many more fit into their places in the whole complex pattern of land occupancy.

Some details of the pattern may be illustrated by the one plantation of Tlahualilo, a property unit organized as a producing unit (Figure 4). The plantation occupies a basin of almost flat land, 30 miles long and 10 miles wide, between low mountain

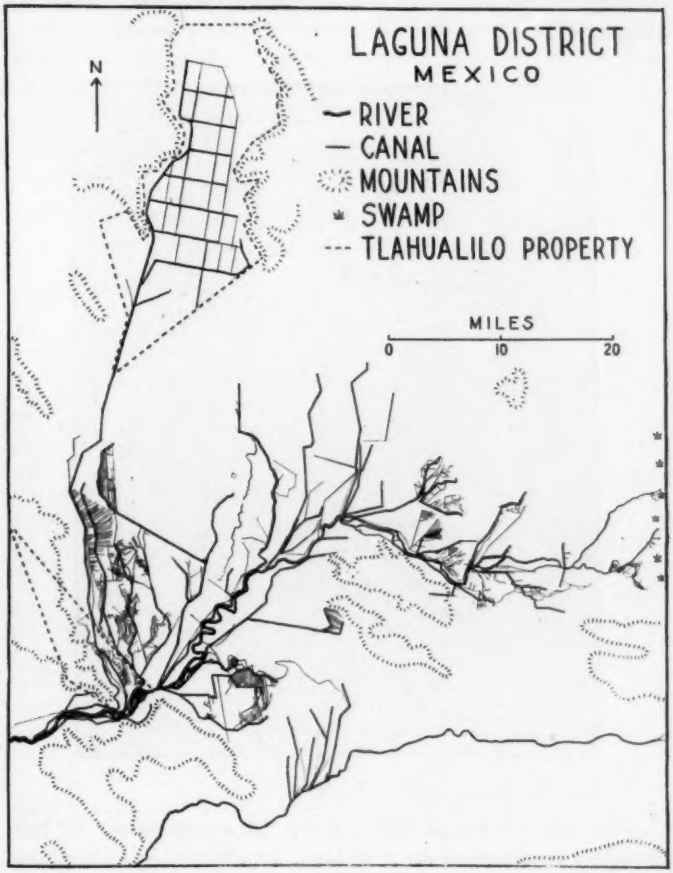

FIG. 3.

ranges. It has rights to a share of water from the Nazas River, part of these rights being derived from ownership of another plantation at the mouth of the Nazes Canyon which happened to possess large water rights but very little good land. The Tlahualilo

canal traverses fifty miles of desert plain from the Nazas River to the plantation (Figure 3) at the hardly sufficient gradient of five inches per mile, passes along the higher western edge of the property, and delivers its water to secondary canals, which in turn distribute to smaller canals and ditches emptying into diked fields (Figure 6).

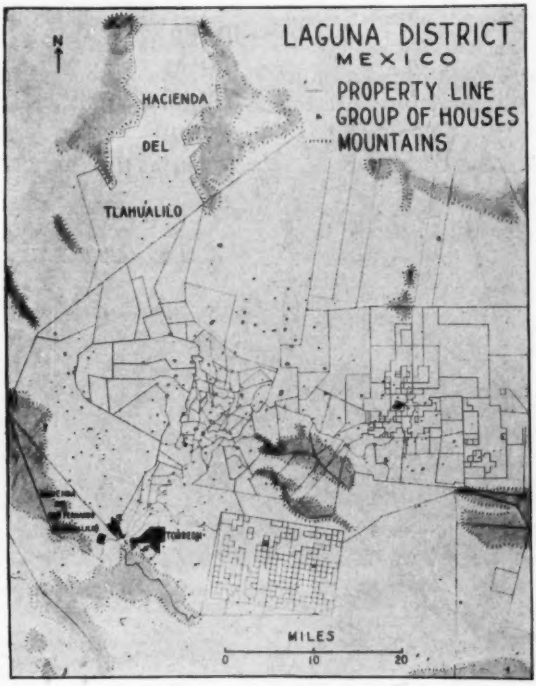

FIG. 4.

The property has an area of about 280 square miles. Of this, a hundred square miles are good land, flat and fertile. Two-thirds of this good land, about 45,000 acres, are prepared for irrigation, restriction to this amount being due to the limitation of available water. The area has been reduced somewhat in recent years by reason of the confiscation of some water rights for the benefit of smaller farms.

The plantation is managed from a central headquarters town. But being too large for central control of farm operations, its agricultural land is divided for farming purposes into twelve *ranchos*, some of them irregular in form where broken by hills or property boundaries, but the others of standard size, approximately 2.5 miles square, containing about four thousand acres, a convenient farming unit. (These are distinguished in Figure 6 as squares bisected by a secondary canal.)

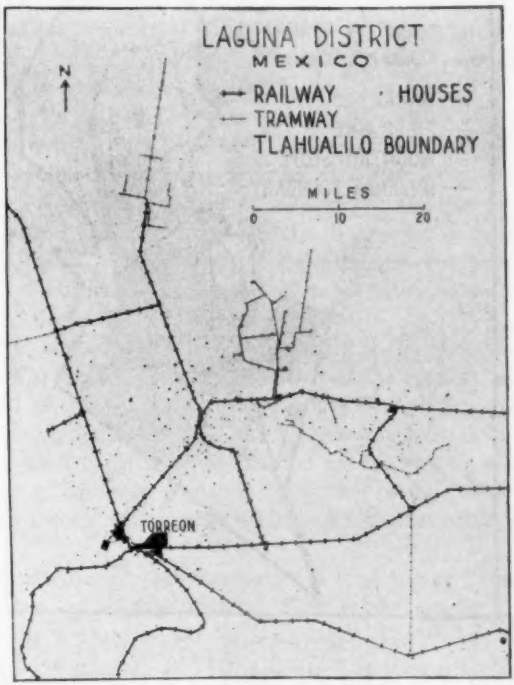

FIG. 5.

For convenience of cultivation each *rancho* is divided into fields of thirty acres, there being 128 such fields in a *rancho* of standard size. They are rectangles 500 meters long and 250 meters wide, (the smallest divisions shown in Figure 6), in each *rancho* 16 rows of them with 8 fields in each row (Figure 7). These thirty acre units are as large as practicable for effective irrigation,

larger than would be possible except on smooth land. Every field is bounded by dikes and reached by irrigation ditches.

Only about half of the fields are available for cultivation at one time. This is due to the seasonal distribution of water. The rainy season in the mountains is sharply defined, in the late summer. Run-off is rapid and there are no large storage reservoirs either in the mountains or on the plain. Consequently, the water must be applied directly to the fields when it arrives. The regular

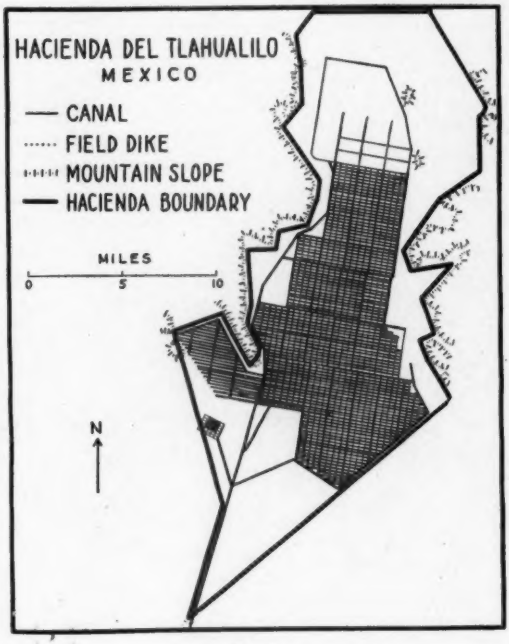

FIG. 6.

time of arrival is in the late summer and autumn just at harvest time, too late to irrigate a growing crop and too early to flood fields occupied by a maturing crop. Therefore, there must be empty fields ready to receive it. Thus fields which have lain fallow are flooded and practically become storage reservoirs of enough moisture to grow their crops the following season, while the harvest fields which are not flooded lie fallow in their turn. With minor crop exceptions, the system requires twice as much land as can

be productive at one time, but since land is plentiful as compared with water, this is not a serious handicap; in fact, it is of some value for soil conservation.

On each *rancho* half of the fields are flooded about three feet deep between August and November. By December the water has soaked in and by February the soil is dry enough for plowing and harrowing. In March and April crops are planted. Cotton is the preëminent crop (Figure 8). No other plant is so suitable, considering the amount of moisture available, the character of the growing season, frost free from March to November, and the marketable commercial product. It occupied 18,000 acres in 1928, almost 90 per cent of the crop land.

Wheat is a desirable supplementary crop, planted after cotton harvest in early winter, maturing before irrigation flooding the following summer, thus using labor at slack times and occupying fields which otherwise would be left idle, and in addition providing a marketable product. Unfortunately, it requires irrigation in January when only a small and uncertain amount of water is available, after the annual flood has subsided. It occupies less than 10 per cent of the land, 2,000 acres in 1928.

Fodder is needed for the work animals of the plantation, and some fields are given over to produce part of the supply. Sorghum fits in well under the circumstances; alfalfa fits less well, requiring more regular irrigation through the year than is generally possible.

Thus an average crop distribution in one *rancho* would be: 1,800 acres of cotton in 60 fields, 1,500 acres of fallow land in 50 fields, 300 acres of wheat in 10 fields, and 240 acres of forage in 8 fields.

The activities of each *rancho* focus in a village (Figure 9), presided over by an administrator under whom are ten foremen, each bossing a gang of ten field laborers. The village contains houses for the laborers and their families, stables for the mules, sheds for farm implements, stacks of fodder, reservoir for domestic water supply, a school, and tram line connection with the outside world of the plantation.

At cotton-picking time the working force is augmented by women and children and floating labor to about four hundred on each *rancho*. Pickers transport their bags of cotton by donkey from the fields to the *rancho* village, where it is credited to them and whence it is carried by tram to the ginnery at the general headquarters of the plantation.

FIGS. 7-9. See explanation on opposite page.

The headquarters town is the central focus for the whole *hacienda*. In it is the manager with his staff of assistants, engineers, chemist, entomologist, meteorologist, doctor, school superintendent, clerks and skilled workers, to man the offices, ginnery and compress, oil mill, machine shops, power house, waterworks, hospital, and school. There are also club houses, playgrounds, theatre, postoffice, stores, a garrison of soldiers, and the terminus of a railway connecting the plantation with the outside world of Mexico.

Tlahualilo is unique and not typical of the Laguna District in size and organization. Most of the properties have less than one thousand acres of irrigated land, and the few others which have large acreage are not operated as units but are divided among tenant farmers. But in agricultural practices Tlahualilo affords a good example of the utilization of natural resources in the region. Moreover, the great *hacienda* is in itself a notable feature of the pattern of land occupancy.

FIG. 7. (*Top*) Tlahualilo looking east from the mountains on the western border. Unirrigated desert in the foreground, main canal across the picture in the middle distance, irrigated fields bordered by dikes and canals in the background.

FIG. 8. (*Middle*) Cotton field early in August, Tlahualilo. Secondary canal bordered by poplar trees at left.

FIG. 9. (*Bottom*) Headquarters of a rancho, Tlahualilo. Water supply reservoir in foreground.

IRRIGATION, WITH SPECIAL REFERENCE TO EUROPE

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The significance of the 20-inch isohyet as marking the *approximate average* limit of humid agriculture and of the 10-inch isohyet as separating the semi-arid from the arid or desert regions has been generally recognized. There is, however, a far less general appreciation of the wide extent of the lands deficient in moisture and the very limited areas now under irrigation.

Data recently compiled[1] indicate that almost one-third of the earth's surface receives less than 10 inches of rainfall, while more than another third receives between 10 inches and 20 inches.

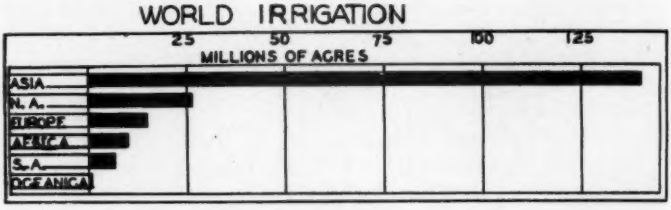


FIG. 1.

Speaking very generally, then, for every acre with sufficient moisture to be capable of large production, there is another acre of limited productivity, and a third so dry as to be practically unproductive. Water supply is obviously the most important factor in determining the potential productivity of the land surface.

To what extent has irrigation been able to remedy this enormous deficit in rainfall? In 1920, the total acreage artificially watered was estimated at approximately 100,000,000, or about 7 per cent of the total cultivated land of the earth. By 1929, although this had been doubled, it amounted in the aggregate to an acreage only about twice the size of the State of California. This would be less than 2 per cent of the land classed as "arid,"

[1] Mead, L., Foreign Markets for Irrigation Machinery and Equipment. U. S. D. C., Trade Promotion Series No. 73, 1929.

i. e., receiving less than 10 inches of rainfall. Even allowing for a larger output per irrigated acre than from ordinary cropping, artificial watering has obviously made but little impression upon the vast dry areas of the earth.

IRRIGATION AMONG THE CONTINENTS

The unequal distribution of irrigated land among the continents is indicated in Figure 1. Asia, with two large densely populated agricultural regions and its vast acreage devoted to

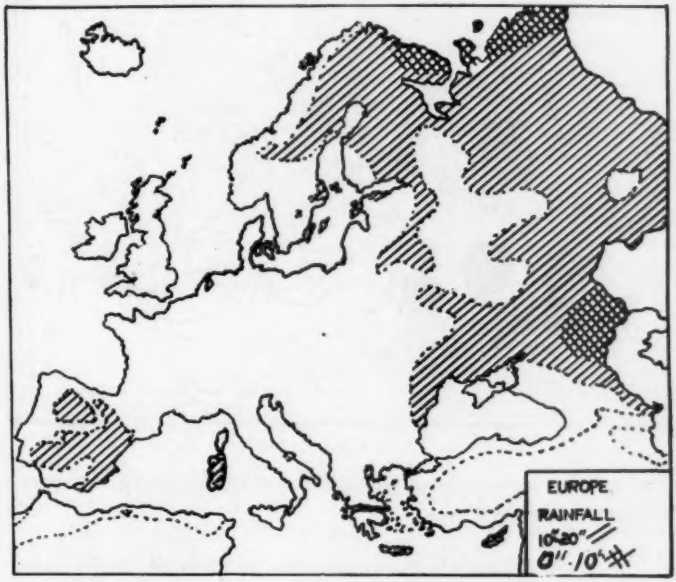


FIG. 2.

the water-loving rice, possesses almost 72 per cent of the world's total. North America, with 13 per cent, chiefly in the United States and Mexico, is a poor second; Europe, with but 7 per cent, is third. Relative to their areas, which would be a fairer basis of comparison, Asia is still far in the lead, with one irrigated acre in every 72 of surface, while on this basis Europe is second, with one acre in every 158 of its area. Rated according to population, Europe ranks lowest among the continents, there being but 31 acres under irrigation for every 100 inhabitants.

Though possessing twice the population density of Asia, Europe has irrigated in proportion to its area, only one-half as much as the former. To a considerable degree this is a tribute to the smaller continent's more favorable distribution of rainfall. Indeed, Europe is the only grand division without an extensive desert area. In addition, that continent is highly industrialized and is able to purchase food supplies from other countries. Asia, on the other hand, is predominantly agricultural and, furthermore,

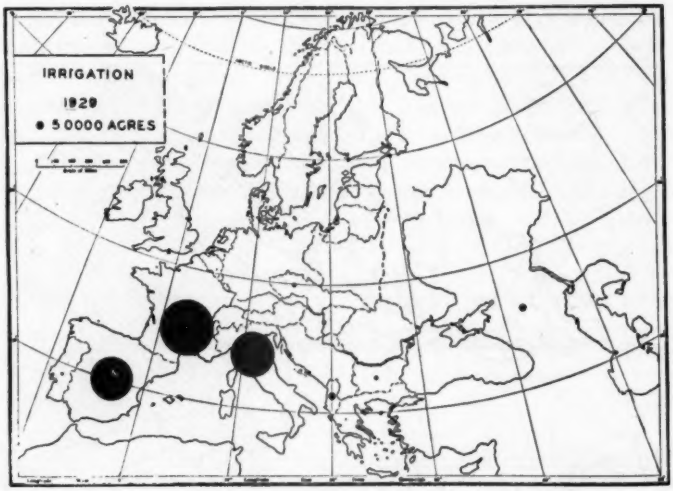


FIG. 3.

has a large acreage in certain crops for whose growth irrigation is almost a necessity.

EUROPE'S RAINFALL AND IRRIGATION

The favorable areal distribution of Europe's precipitation is shown in Figure 2. More than one-half of the continent receives over 20 inches annually, while the area with less than 10 inches is negligible, less than 5 per cent, in fact. The zone receiving from 10 inches to 20 inches lies in the extreme northeast, and east, with a small area in Spain.

Figure 3, showing the extent of irrigated acreage by countries of Europe, illustrates several interesting features, especially when compared with the map of rainfall. The most striking fact is the

concentration of irrigated acreage in the western Mediterranean, France, Italy, and Spain accounting for over 90 per cent of all European lands artificially watered.

A comparison of Figures 2 and 3 reveals the apparently anomalous situation that the major part of the lands receiving less than 20 inches of rain are in the northeast, while the principal irrigated areas are in the opposite corner—the southwest. Apparently, the relation of irrigation to annual precipitation is not so simple as it might at first appear.

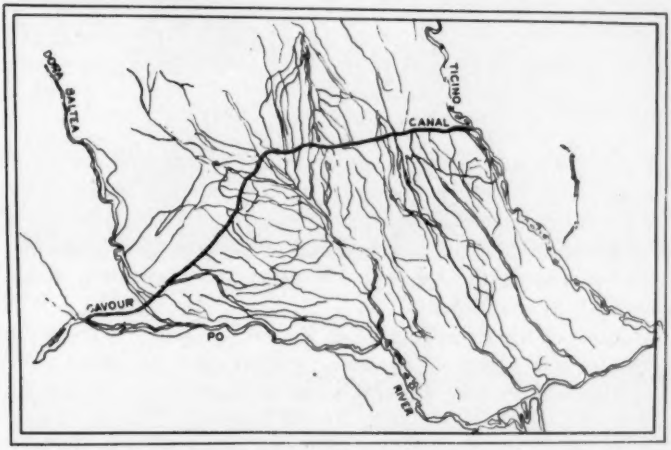


FIG. 4. Network of irrigation canals between the Ticino and Dora Baltea, in the Upper Po Basin.

PRECIPITATION AND AGRICULTURE

To the question of how much rainfall suffices for ordinary agriculture, the annual precipitation data provide but a very incomplete answer. *When* the rainfall comes may be just as important as *how much* is received . Europe is, as we have seen, very fortunate in its areal distribution of moisture, but in the south it is handicapped by a bad seasonal distribution. A marked summer minimum of rainfall combined with high temperatures produces drought, even though the annual amount be over 20 inches. Conversely, northeastern Europe receiving from 10 inches to 20 inches but with a summer maximum and a smaller evaporation coefficient, may have sufficient moisture for ordinary agriculture. Thus,

throughout much of the Mediterranean the summer growth of any but a few drought-resisting plants necessitates artificial watering. Jerusalem has about the same annual rainfall as does London, but the one is in a desert, the other in a garden.

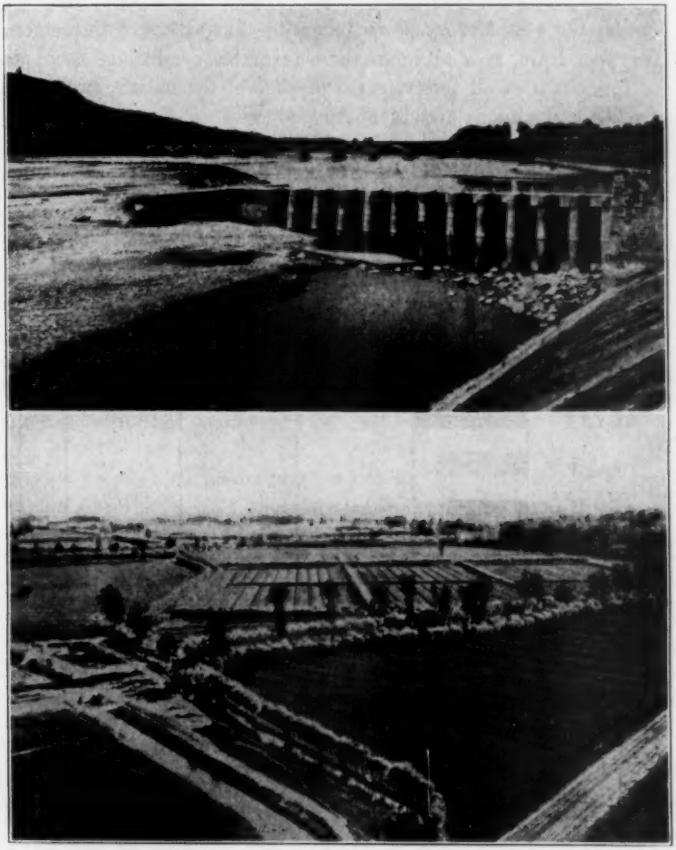
But why the concentration of irrigation in the *western* rather than the *eastern* Mediterranean section of Europe? In the former there is a greater degree of political stability, of cooperative effort, of scientific agricultural knowledge. The physical bases, alluvial plains with snow and glacier-fed streams, are available. Again, the great industrial population of northwestern Europe constitutes an excellent market, easily accessible for vegetables, fruits, and flowers from the irrigated fields in the southwest.

SPAIN VS. FRANCE AND ITALY

In Spain most of the irrigated lands are semi-arid and would be used only for sheep pasture if unwatered. Two-thirds of its irrigated land is found along the lowlands margining the meseta on the north, south, and east—a fringe of luxuriant gardens around a barren and desolate plateau. Many of these irrigation canals were built by the Moors.

Much of the irrigated land of France and Italy, on the other hand, is in a region of moderate rainfall, and the addition of irrigation water with accompanying increased yields represents one of the methods of making agriculture more intensive, quite similar to the extensive use of fertilizers or more careful tillage. The western, or upper, Po basin is the irrigation region *par excellence*. The northern plain of Italy was formerly an extension of the Adriatic, and the same rivers that transformed it from a gulf to a plain are now busy watering the fields and energizing the factories of that populous region. The upper Po and its tributaries are torrential, but in the lower portion the river winds sluggishly across a broad flat alluvial plain. Consequently, in the upper portion, water power and irrigation development have made great progress; in the lower, drainage and flood control are necessary. The superiority of the Alpine, or northern, tributaries in volume and regularity of flow from the snows and ice of the Alps has given the north side of the Po ten acres of irrigated land to every one on the south. About Milan the countryside has the appearance of a great garden with a network of canals. The rainfall of that section is greater than in central Illinois; yet the

abundance of streams makes even irrigation of pastures profitable. Figure 4, a map of irrigation between the Dora Baltea and Ticino west of Milan, gives an excellent idea of the intricate maze of canals in this region. The Cavour canal, carrying water from the



(*Photos by E. Mead.*)

FIG. 5. (*Above*) Head of the Cavour Canal.
FIG. 6. (*Below*) View in the irrigated region of the Upper Po Basin.

upper Po for over 50 miles to the Ticino, is shown running parallel to the foothills of the Alps. Figure 5 shows the head of the canal, the nearly dry Po channel in the foreground, the diversion dam, and the canal leading off to the left. In its course the canal

is carried under and over many streams and other canals. The upper Po waters are relatively warm; those of the Dora Baltea fed by melting snow are cold. By proper regulation of the amount admitted into the canal from each, considerable temperature control over the irrigated fields is possible. Figure 6, a view over the countryside near Milan, shows the garden-like aspect of the region. Northern Italy, as a result of these favorable conditions, accounts for four-fifths of all the irrigated acreage of the nation, two of its provinces, Piedmont and Lombardy, alone possessing 72 per cent.

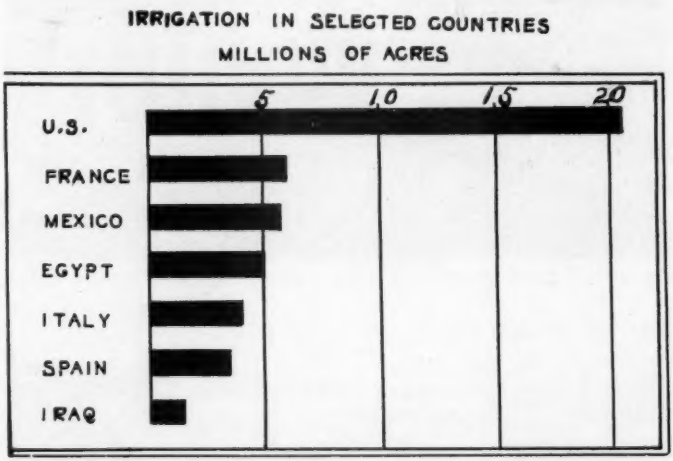


FIG. 7.

It is interesting to note that some of the historically famous irrigated regions are smaller than several of which little is heard. Figure 7 represents diagramatically the irrigation in certain selected areas. France, and even Mexico, is shown to have larger areas artificially watered than has Egypt. Part of the greater publicity given such regions as the valleys of the Tigris-Euphrates and the Nile is due to their more spectacular setting—typical oasis gardens in a barren desert. The great expansion in irrigation in recent times has been in the semi-arid rather than the desert regions, and the use of modern machinery and large capital has served to dwarf some of the world's old irrigation valleys. Thus the United States alone has about four times the irrigated area of Egypt.

A METHOD OF DETERMINING THE DEGREE OF COINCIDENCE IN DISTRIBUTION OF AGRICULTURAL USES OF LAND WITH SLOPE-SOIL-DRAINAGE COMPLEXES

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University of Chicago

It is common knowledge that in most farming regions certain types of land are better suited than others to the crops there raised, and that crops consequently tend to be concentrated on these better lands. This knowledge is based on numerous field observations, on repeated statements by farmers, and on comparison of topographic and soil maps with maps showing distribution of crops. There has been a need, however, for a method of determining quantitatively the degree of coincidence in distribution that exists between crops, pasture, and other agricultural uses of land, and slope-soil-drainage complexes.

Within the last few years geographers[1] have perfected a method of detailed field survey which makes it feasible to record on one map the facts of land utilization and the associated facts of slope, soil, drainage, and natural vegetation, in an accurate, legible,

[1] The development in the United States by geographers of field survey methods for agricultural areas is evinced by the following chronological list of articles:

Jones, Wellington D. and Sauer, Carl O.: "Outline for Field Work in Geography," *Bulletin of the American Geographical Society*, Vol. 47 (1915), pp. 520-525.

Sauer, Carl O.: "Proposal of an Agricultural Survey on a Geographic Basis," *19th Annual Report of the Michigan Academy of Science* (1917), pp. 79-86.

————: "Mapping the Utilization of the Land," *Geographical Review*, Vol. 8 (1919), pp. 47-54.

————: "A Soil Classification for Michigan," *20th Annual Report of the Michigan Academy of Science* (1920), pp. 83-91.

Jones, Wellington D. and Finch, V. C.: "Detailed Field Mapping in the Study of the Economic Geography of an Agricultural Area," *Annals of the Association of American Geographers*, Vol. 15 (1925), pp. 148-157.

Whittlesey, Derwent S.: "Field Maps for the Geography of an Agricultural Area," *Annals of the Association of American Geographers*, Vol. 15 (1925), pp. 187-191.

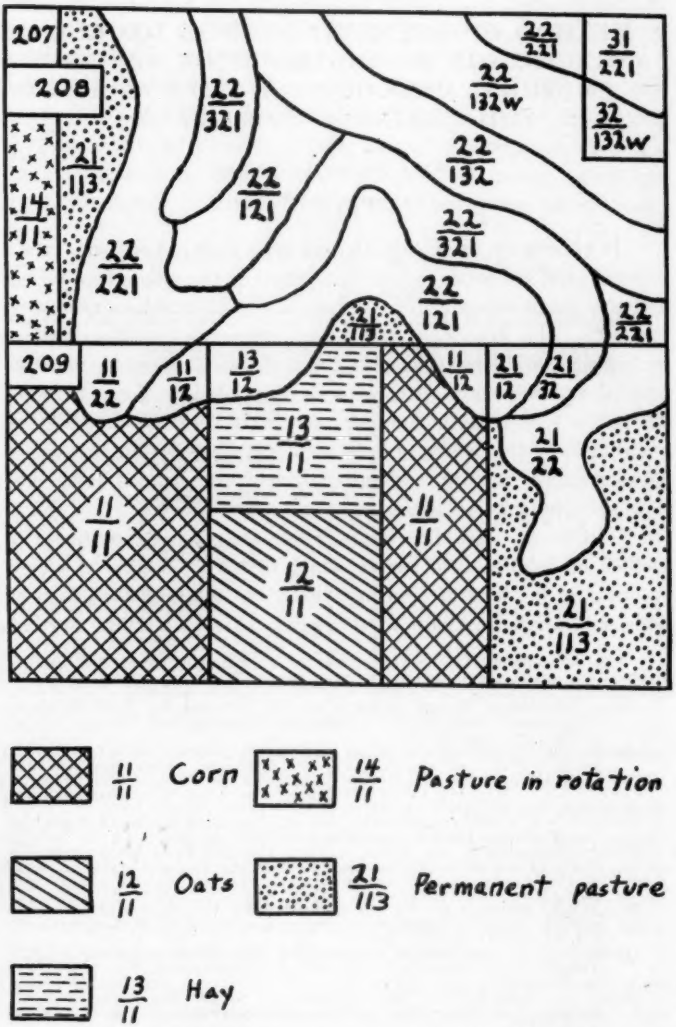
Davis, D. H.: "Objectives in a Geographic Field Study of a Community," *Annals of the Association of American Geographers*, Vol. 16 (1926), pp. 102-109.

McMurry, Kenneth C.: "Soil Mapping in Geographic Field Studies," *Annals of the Association of American Geographers*, Vol. 16 (1926), pp. 110-116.

Cosby, Stanley W.: "Utilization of the Soils in the Gilroy Region," *Hilgardia*, Vol. 1 (1926), pp. 455-478.

Whittlesey, Derwent S.: "Devices for Accumulating Geographic Data in the Field," *Annals of the Association of American Geographers*, Vol. 17 (1927), pp. 72-78.

Platt, Robert S.: "A Detail of Regional Geography—Ellison Bay Community as an Industrial Organism," *Annals of the Association of American Geographers*, Vol. 18 (1928), pp. 81-126.



Field map of one-fourth square mile, illustrating fractional notation scheme for recording in detail various characteristics of use-site complexes. See explanation on opposite page.

and usable manner. The accompanying section of a field map illustrates the method.

By field inspection, areas uniform throughout in the details of use and of associated natural site characteristics are delimited on a map of a scale sufficiently large (e. g., 1:20,000) to carry the details desired. Fractional notations are employed to record these details. The numerator of the fraction gives the details of use of the area to which it applies, the denominator the details of site. The left-hand digit of the numerator gives the major fact of use, such as for crops, for permanent pasture, etc. The second digit of the numerator gives a detail of this use, such as kind of crop or type of pasture. Additional digits may be employed to record further details, such as quality of crop or pasture. The left-hand digit of the denominator records the angle of slope of the area to which the fraction applies, the second digit the soil type, the third digit the type of natural vegetation (if not removed), the fourth digit drainage (if it be inadequate). As the field investigator, traversing the area being mapped, encounters an areal change in any one of the details recorded, either of use or of site, he enters on the map a line separating two different use-site complexes.

From such a map it is possible to determine quantitatively the degree of coincidence in distribution between (a) the various items

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Use recorded in numerator of fraction, as follows:
Crop land—left-hand digit—1.
Crops—second digit from left:
Corn—1.
Oats—2.
Hay—3.
Pasture in rotation—4.
Permanent pasture land—left-hand digit—2.
Type of pasture—second digit from left:
Grass—1.
Wooded—2.
Idle land—left-hand digit—3.
Potential use—second digit from left:
Crops—1.
Pasture—2.
Farmsteads are numbered serially (207,208,209); descriptions in notebook carry appropriate numbers.
Site characteristics recorded in denominator of fraction, as follows:
Angle of slope—left-hand digit:
From 0 to 7 degrees—1.
From 7 to 14 degrees—2.
More than 14 degrees—3.
Soil profile—second digit from left:
Upland prairie—1.
Upland woodland—2.
Floodplain woodland—3.
Natural vegetation (where not destroyed)—third digit from left:
Oak-hickory forest—1.
Elm-maple forest—2.
Prairie—3.
Drainage, if inadequate, is indicated by W after the denominator; if adequate, no record.
On this map, the various uses of high-class land (slope less than 7 degrees, upland prairie soil profile, drainage adequate) are picked out for measurement by the addition of bendays; in the office, colors are employed.

or combination of items of land utilization recorded and (b) the various characteristics or combinations of characteristics of the land thus used. For example, within a tract surveyed, all areas in corn, in oats, in hay, in permanent pasture, on land with a given degree of slope, a particular soil profile, and a certain type of drainage, can be measured, as well as the areas in these various uses on other kinds of land (see map).

Several detailed surveys employing this method of mapping agricultural occupance and utilization of land have been made by the departments of geography at the University of Chicago and the University of Wisconsin.

In the spring of 1928 a group of graduate students from the University of Chicago made such a survey of the farming area served by and supporting the village of Orland, 22 miles southwest of the heart of Chicago on the Wabash Railroad. The objectives of this survey were stated as follows: to discover (through observation, interview, and perusal of the literature), to depict (by maps, photographs, statistical tables, and written statements), to analyze, to explain (in terms of the natural site characteristics of the land used, the density and character of the population using the land, the past uses made of the land, and the connections and other relations of the area under study with the outside world), and to appraise, the present occupance and utilization of the area embraced within the limits of the Tinley Park Community (the village and the farms using the village as a trade center). A map of the type described in this paper constituted the foundation of the survey.

The area survey covered 10,953 acres (17+ sq. miles), of which 9,973 acres were in farms, 7,323 acres in crops, and 1,543 acres in permanent pasture. Corn, oats, and hay, in rotation, were found to occupy most of the land in crops, and to be largely fed to livestock. Dairying was found to be the major farm interest. The several natural complexes recognized and mapped in this study may be grouped into three classes:

I. High-class land, i. e., slope less than 7°, upland prairie soil profile (largely Carrington silt loam), drainage adequate; such land constituted 52 per cent of the area surveyed.

II. Medium-class land, i. e., slope less than 7°, upland woodland soil profile (largely Miami silt loam), drainage adequate; 15 per cent of the area surveyed.

III. Low-class land, i. e., all other site complexes; 33 per cent of the area surveyed.

The extent to which the high-class land was used for crops rather than for pasture, and for corn rather than for oats or hay—in other words, the tendency to employ the best land for the most productive uses—is revealed by the following statements:

I. High-class land, which constituted 52 per cent of the area surveyed, carried 78 per cent of the corn acreage, 70 per cent of the oats acreage, 64 per cent of the hay acreage.

II. Medium-class land, which constituted 15 per cent of the area surveyed, carried 10 per cent of the corn acreage, 11 per cent of the oats acreage, 18 per cent of the hay acreage.

III. Low-land land, which constituted 33 per cent of the area surveyed, carried 12 per cent of the corn acreage, 20 per cent of the oats acreage, 19 per cent of the hay acreage, 40 per cent of the permanent pasture acreage.

Field maps of the type herein described serve various other purposes than making possible the determination of the degree of coincidence between different kinds of land utilization and the several types of land employed. For example, from the data on the field map, a map may be made showing the pattern of utilization, both in its large lineaments and in detail, as well as maps of soils and of slopes, the latter supplementing in a most useful manner even a very detailed contour map. As the field map is made, farm boundaries are recorded on it, as well as types of roads, as to surface and resulting usability. With these data available, a valuable map may be made which shows the pattern of farms, all tied to their trade center, through their farmsteads, by the highway system.

In a field study involving the making of such a detailed record, many data are gathered which are recorded in the notebook rather than on the field map. For example, at each farmstead the population thereof, and the numbers of different kinds of livestock, are ascertained. From these data, maps of distribution and density of population, and of livestock distribution and density, can be constructed.

Scientific investigation, in geography as in any other discipline, is well-grounded in the degree to which it rests on quan-

titative data. In the study of agricultural occupance and utilization of regions, the method described in this paper, insofar as it has been tried, appears to be effective in accumulating quantitative data desired by the geographer. It is to be hoped that the method may now be tested in regions differing greatly, both in use and in the character of the land employed, from the sections of northern Illinois and southern Wisconsin where the studies referred to have been made.

FIG. 1. (*Upper left*) Ship canal rolling stock.
FIG. 2. (*Upper right*) Transport used in Manchester.
FIG. 3. (*Below*) Unloading equipment.

THE MANCHESTER SHIP CANAL

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During the present time of canal agitation in the United States the great ship canals of the world are attracting much attention. A study of the Manchester Ship Canal was made in part so as to be able to contrast it with internal waterway enterprises in this country.

The building of the Manchester Ship Canal was a great engineering feat and a magnificent venture made in spite of determined opposition on the part of railways, the port of Liverpool, and many land holders. The advantage of a waterway from eastern Lancashire to the sea was recognized long before the days of the present ship canal. The Duke of Bridgewater in 1722 constructed an extension of the canal from his collieries at Worsley to Manchester and thence to the Mersey River at Runcorn. This canal was navigated by barges carrying about 50 tons of cargo but was inadequate for the increasing amounts of cotton, timber, grain, and other goods demanded in the Manchester area. In later years railroad rates were declared to be too high, and agitation for a ship canal started as early as 1825. It was not until 1882 that definite steps were taken which culminated in the opening of the Manchester Ship Canal by Queen Victoria in 1894[1].

It was not easy to prove the necessity of a canal that would accommodate ocean vessels. Stormy debates in Parliament, hundreds of petitions, and many long discussions are on record about the canal and the plan of its course. Finally, a lock canal plan was adopted, although Manchester is only 70 feet above sea level. The Mersey estuary, the Irwell River, and the old Bridgewater Canal complicated matters. Since the rivers meander widely and since the plan was for a straight canal, it was necessary to undertake heavy cutting through the valleys, impeded by floods and tides. The old canal passed over the Irwell River at Barton, near Manchester, on an aqueduct too low to permit steamers to pass under it. The plan of the ship canal called for the use of this portion of the river, and the old canal was essential as a feeder. Hence,

[1] Leech, B., History of the Manchester Ship Canal. Manchester, 1907.

it was thought best to purchase the Bridgewater Canal outright and to provide means for its maintenance. A notable engineering project made possible a swing aqueduct in place of the original crossing of the river. The water in the swing portion is retained by closing gates at each end, and similar gates close the fixed portions. When the aqueduct is swung, in the manner of a swing bridge, large steamers may pass on the ship canal underneath. This Barton aqueduct is one of the show places of England.

The ship canal is 35½ miles long. Its principal docks are at Manchester. The access channel has been excavated to a depth of 13 feet below Liverpool Bay datum. From Eastham to Ellsmere Port the depth is 30 feet, and from Ellsmere Port to Manchester 28 feet. The bottom width is 120 feet, except at a few places where it is 170, 175, or 180 feet. There are two parallel locks at Eastham which are open to estuary level whenever the tide rises more than 26.2 feet above Liverpool Bay datum. When the tide is below this level, access is obtained by means of the locks. A vessel can be passed through the largest lock (600 feet by 80 feet) in eight minutes or less.[2]

H. G. Moulton in 1912 came to the conclusion that the Manchester Ship Canal was a losing venture.[3] True, at that time there seemed little prospect that the canal would pay for itself. The expenditure on capital account up to December, 1909, had been 16,790,491 pounds sterling. If it had been known in 1894 that the cost would exceed more than twice the amount of the original estimate, the canal, admittedly, would not have been built. Many unforeseen difficulties had been encountered, such as silting, failures of sea embankments, defects in locks and sluice gates, and deficient dock and trade arrangements. The anticipated tremendous traffic had not been realized, the company had not been able to pay the interest on its debt, and the outlook for the future was not encouraging. In 1909, Manchester business men (quoting Moulton) were frankly admitting that the canal had been a great disappointment.

In the summer of 1928, however, a different attitude was found among Manchester business men. They pointed with pride to the excellent facilities and splendid efficiency at the docks, to the extensive late additions to equipment, and to the crowding of

[2] Port of Manchester, Official Sailing List and Shipping Guide, (1928), p. 23.
[3] Moulton, H. G., Waterways Versus Railways, (1912), p. 149.

traffic on the canal almost throughout its length. The Manchester Dock estate now covers an area of 406½ acres, including a water space of 120 acres, and quays 5⅝ miles long. The storage area is 286½ acres. Eight docks ranging in size from 780 x 120 feet to 2700 x 250 feet have been constructed. The Dock equipment includes 255 cranes (hydraulic, steam, and electric), 36 electric hoists, a floating, self-propelling, derricking and revolving crane of 60 tons lifting capacity, a fleet of lighters, 6 floating pontoons, a coaling crane, 54 locomotives and 2,432 railway cars, 30 hydraulic and 47 electric capstans, 69 transit sheds and warehouses of which 16 are of five floors and 13 of seven floors, a cold storage chamber of 300,000 cubic feet capacity, and, in brief, all modern appliances for port efficiency.

The Manchester business men quoted statistics that showed a great increase in trade and pointed to the excellent prospects for future trade. They showed that the current interest, together with dividends on the investment, had been paid in recent years in spite of the fact that up to December 31, 1927, the expenditures amounted to 19,675,290 pounds. In values of total imports and exports, Manchester was the fifteenth port of the United Kingdom in 1894 (the first year of the ship canal) but by 1927 it had become fourth. In tonnage entered, it was the twenty-eighth port in 1894 and the ninth in 1927. In tonnage cleared, it rose from twenty-third in 1894 to tenth in 1927. The total revenue of the canal, which has been more than a million pounds annually since 1919, amounted to 1,576,237 pounds in 1927.

It is evident that the canal has been of much value to Manchester and the Lancashire industries. The city has developed from a textile center into the pivotal point for a host of other activities, and surely the waterway has attracted interests that rely on ocean and internal transportation. It is also evident, however, from comparative studies, that if this canal, providing an outlet to the sea for one of the world's great and intensive industrial areas, is a losing venture, certainly no tremendous financial profit could be expected from a comparable ship canal penetrating the interior of any country.

PRICE PLANS IN EASTERN MARKETS AS RELATED TO NATURAL PRODUCTION OF MILK

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A milk-marketing plan is a structure formulated to facilitate collective bargaining, as to price, between producers and distributors. Most of the price plans now in operation have been put into effect since 1920. Thus, the Philadelphia plan went into effect January, 1921; the New York plan, May, 1921; the original Pittsburgh plan, May, 1922; and the Baltimore plan, January, 1924.

People drink milk in winter as well as in summer. Nature provided that cows should freshen in spring and early summer. This allowed both dams and off-spring the chance of getting into good condition during a warm season of abundant grass before compelling them to withstand the rigors of winter when food is difficult to obtain. Ordinarily, a cow produced only enough milk to nourish a calf until it was able to shift for itself. Hence, when the cow was brought into use as a producer of milk for human consumption, man had to apply his ingenuity to adjust nature's provisions to the new human desires.

The following discussion will attempt to show the uses to which milk-marketing plans have been put in adjusting natural milk production so that it will conform more nearly to market consumption of milk. Each of three principal types of plans will be discussed. This discussion will be preceded by a brief presentation of the values of certain farm products, and differences between seasonal variation in the production and consumption of milk.

Values of Farm Products. The total value of farm products in the United States in 1926 was estimated to be slightly under 17 billions of dollars. Dairy products represented approximately three billions of dollars, or about 18 per cent of the total value. The farm value of milk in fluid uses was estimated to be about two billions of dollars, or more than that of corn, of swine, of cotton, or of any other farm product (Figure 1).

Changing Natural Production to Meet Market Demand. During the pioneer days of dairying, most milk was produced during the summer months. Farmers, in large part, accepted the natural order that cows should freshen in spring and early summer. They stripped out what milk was available during the late spring, summer, and early fall and allowed their cows to go dry during the winter.

Butter and cheese factories located in regions where natural production prevailed, were closed during the winter months. Thus, six butter and cheese factories in a dairy region in Cortland

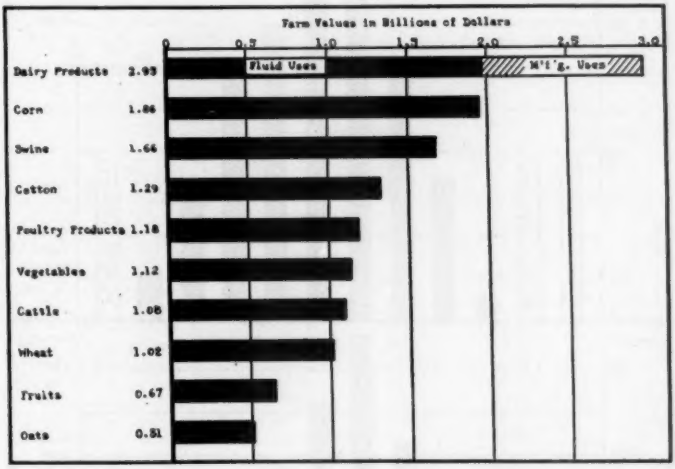

FIG. 1. Estimated values of certain farm products in United States, 1926. (From U. S. D. A. Crops and Markets, July, 1927, pp. 250 and 251.)

County, New York, on which data were procured for two years prior to 1906, received no milk during December, January, or February (Figure 2). Factories were opened the latter part of March and closed the early part of November. The volume of milk received in June, the month of heaviest production, was 86 per cent higher than the nine-month average, and eight times the volume received during November.

In order to conform to the year-round demand of milk, definite action in the way of selection and feeding was necessary to increase production, and breeding had to be controlled to get winter production. Some stimulus was necessary to induce a farmer to

take the necessary action. Generally speaking, feed costs are higher in winter than in summer, and a producing cow requires better shelter and more care during the winter than a cow which is dry during this season. Payment of a higher winter price was the only way to induce farmers to produce winter milk.[1] Consequently, milk distributors paid a price higher in winter than in summer. For

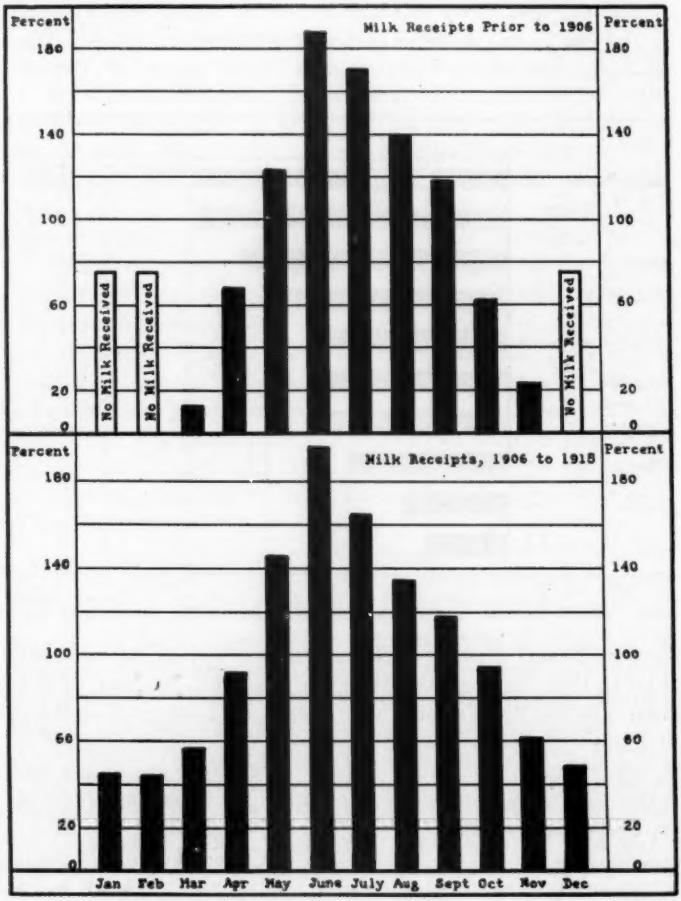

FIG. 2. Monthly variations in milk receipts at certain butter and cheese factories in Cortland County, New York.

example, the price paid for milk at ten shipping stations in Cortland County, New York, 1906 to 1915, averaged $1.77 per hundred pounds during November, December, and January, and $1.12 per hundred pounds for May, June, and July.[2] The winter price was 65 cents higher than the average price during the low months.

TABLE I—MONTHLY VARIATION OF MILK RECEIPTS AT BUTTER AND CHEESE FACTORIES IN CORTLAND COUNTY, NEW YORK, 1904 TO 1915.*

Months	Daily average of milk receipts per factory			
	Six butter and cheese factories for two years prior to 1906		Seven butter and cheese factories 1906 to 1915	
	Average volume in pounds	Per cent of nine months average volume	Average volume in pounds	Per cent of twelve months average volume
January			2,264	44
February			2,215	43
March	550	12	2,925	57
April	3,153	67	4,709	91
May	5,768	123	7,582	147
June	8,721	186	10,100	196
July	7,971	170	8,511	165
August	6,533	139	7,009	136
September	5,520	117	5,999	116
October	2,980	63	4,909	95
November	1,090	23	3,177	62
December			2,558	49
Average	4,698	100	5,163	100

* Pennsylvania State College, Agricultural Experiment Station Bulletin 208, p. 15, Table 7, December, 1926.

Stations shipping fluid milk forced butter and cheese factories within competing areas to keep open the year around in order to hold their milk supply. Thus, butter and cheese factories in Cortland County, New York, from 1906 to 1915, received milk continuously throughout the year, though their volume in June still remained over three times larger than in November (Figure 2).

[1] Recent farm management studies indicate that fall-freshening cows produce a greater volume of milk at a unit cost no higher than that for spring-freshening cows. Winter production costs for the fall-freshening cows are, however, higher than summer costs for these same animals.

[2] Penn. Agr. Exp. Sta. Bull. 208, p. 17, Table 8.

MONTHLY VARIATION IN PRODUCTION AND CONSUMPTION

Although milk production during the winter months has been greatly increased, the monthly variation in milk production still remains far wider than the variation in milk consumption. Thus, milk production in November, the month of lowest volume, in

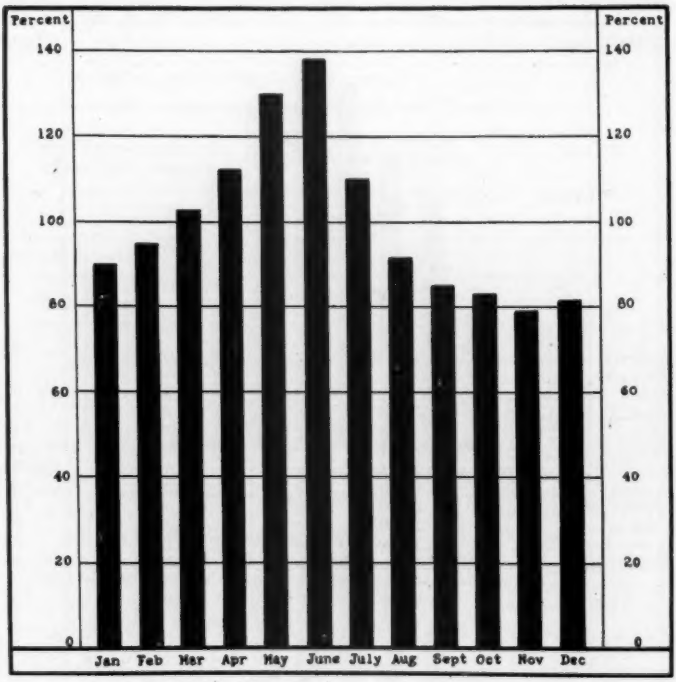

FIG. 3. Average monthly variation in production in the New York, Chicago, and Pittsburgh Milksheds.

New York, Chicago, and Pittsburgh milksheds (Figure 3) averaged 79 per cent of the year's average, and the production in June, the month of highest volume, averaged 137 per cent of the year's average, or 58 per cent higher than the November production.

Average sales of bottled and bulk milk in New York, Chicago, and Pittsburgh during August, the month of lowest demand, were 97 per cent of the year's average (Figure 4). Fluid sales in these

markets in June, the month of greatest demand, were 103 per cent of the year's average, or 6 per cent higher than those for August.

The maximum difference of 6 per cent in sales in these markets is to be compared with a maximum difference in production of 58 per cent, or over nine times the maximum variation in fluid sales.

TABLE II—MONTHLY VARIATION IN SALES OF BOTTLED AND BULK MILK, AND IN PRODUCTION, IN THE NEW YORK, CHICAGO AND PITTSBURGH MARKETING AREAS (YEAR'S AVERAGE = 100).*

Month	Sales	Production
January	98.7	90
February	99.4	95
March	100.6	103
April	100.4	113
May	100.1	130
June	102.8	137
July	99.0	111
August	96.7	92
September	100.5	85
October	102.0	83
November	100.8	79
December	98.4	82
Average	100.0	100

* Data on sales and production from the following sources:
(1) Ill. Agr. Exp. Sta. Bull. 269, p. 495, Table 18. Average monthly sales in Chicago, 1920 to 1922=100, p. 484, Table 9. Average monthly production in Chicago Milkshed, 1920 to 1922=100.
(2) U. S. D. A. Technical Bull. 73, p. 23, Table 11. Monthly averages of quarts of grade B milk in the New York market, 1919 to 1924=100.
(3) Cornell University. F. Ec. Seasonal Variation of Milk Shipping Stations, 1924.
(4) For Pittsburgh, through courtesy of the Dairymen's Cooperative Sales Company. Average monthly sales of bottled and bulk milk, 1922 to 1926=100. Average monthly production, 1922 to 1926=100.

Seasonal variation in production is a problem of the utmost significance in fluid milk markets. Otherwise expressed, this is the problem of "surplus."[3] Surplus, as used in this discussion, refers to the volume of milk (in a fluid milk market) which is not used for bottled or bulk-milk sales. The best way to handle the surplus problem is through use of a workable milk-marketing plan based upon economic principles.

[3] In a market on a flat price system, the price paid may be "weighted"—that is based upon the values of milk as utilized for the market. This, however, penalizes the distributor having a heavy surplus to the benefit of the distributor having a small surplus.

MILK MARKETING PLANS

As stated, a milk-marketing plan is a structure formulated to facilitate collective bargaining, as to price, between producers and distributors. It is usually safe to say that the plan used in any given market has been developed to solve certain problems which were most pressing in that market. Consequently, marketing plans differ widely.

There are three principal types of milk-marketing plans. One of the most common types is the "classification" or "use" price

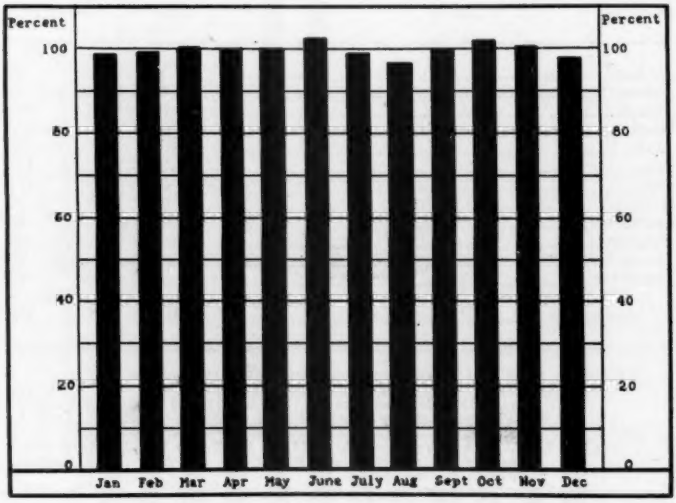

FIG. 4. Average monthly variation in bottled and bulk milk sales in New York, Chicago and Pittsburgh.

plan. This serves as a standard for selling milk by a producers' co-operative association to distributors at prices based upon its market value in different uses, as fluid milk, cream, evaporated milk, butter, or cheese. This type of plan is used in the New York and Boston markets.

Another type is the "basic-surplus" price plan. This provides for paying each producer a higher price for a uniform production of milk, and a lower price for surplus over his uniform volume. This type of plan is used in the Philadelphia market.

A third type is the "combination" price plan. This is a combination of the classification or use plan and the basic-surplus plan. Under this combined plan, milk is sold to distributors on a classified basis, and proceeds are distributed so that a producer receives higher returns for a uniform production than for a widely fluctuating volume. This type of plan is used in the Pittsburgh, Baltimore, and Connecticut markets.

The "classification" price plan may be operated in two ways, as follows:

1. An arrangement with a market pool in which an average price is paid to all organized producers in the milkshed. This "market pool" plan is used in New York.

2. An arrangement with no pooling by distributors. This "multiple pool" plan is used in Boston.

The "combination" price plan may be operated as follows:

1. Each producer states his "basic" or "specified" volume, and penalties are deducted for any volume over or under the basic volume. The so-called Connecticut (combination) price plan exemplifies this method.

2. The "basic" volume is determined by each producer's production during fixed months, and a balance maintained between money received and money distributed through use of an association's "adjustment" fund. The Baltimore price plan is an example.

3. The "basic" volume is determined so that it corresponds closely to fluid sales, a fluid price being paid for this volume, and a lower price for the surplus. The plan used in the Pittsburgh market is an example of this "equalizing value" price plan.

CLASSIFICATION PRICE PLANS

A classification price plan is a structure to sell milk to buyers in a market at a series of prices based upon the values of milk in different uses. Thus, there may be one price for milk used in fluid form; another price for milk separated to be used as cream; and other prices for milk manufactured.

The fundamental reason for paying different prices for milk in different uses is that the value of milk for fluid needs at certain seasons is not the same as the value of surplus milk for these seasons. The fluid-milk value at certain seasons is considerably greater than surplus values, while at other seasons there is less difference in their respective values.

During the period of least surplus, such as September, October, November, and December, the volume of milk in fluid uses is greater than that in surplus uses. The price of milk for fluid needs during this least surplus period might be higher than that returned for manufactured products, in order to encourage a production sufficient to supply fluid needs at this period. The result is that the average price to producers, including fluid-milk and surplus prices during this least surplus period, is governed largely by the price necessary to encourage production for fluid needs.

During the season of most surplus, such as April, May, and June, the volume of milk in surplus uses is greater than that in fluid uses. Then the average price to producers is governed largely by the value of milk in surplus uses.

THE NEW YORK CLASSIFICATION PRICE PLAN

The New York price plan has five main classifications for the different uses of milk. Milk sold to a large buyer may be divided into four or five uses. Most buyers do not have more than three uses, and in some cases a distributor has only one use for milk.

The five classifications on which milk is sold are: (1) in fluid form, (2) cream and ice cream, (3) evaporated whole milk, sweetened whole condensed, milk chocolate, whole milk powder, soft and foreign cheese, (4) butter, and (5) American cheese.

Average Price Paid to Farmers. The price which each farmer receives for milk depends upon its total market value as derived from its various uses, and the total volume. Calculations have been made for the average price paid to producers. Thus, in an example used in Figure 5, the market value of milk used in fluid sales was $3,552; in cream and ice cream, $720; evaporated whole milk, sweetened whole condensed, milk chocolate, whole milk powder, soft and foreign cheese, $485; in butter, $194; and in American cheese, $209; or a total market value of $5,160. Since the total volume sold was 200,000 pounds, the average price was $2.58 per hundred pounds. Association expense is deducted from the average price to obtain the net average price returned to producers.[4] Each producer is paid the net average price based upon his contribution of volume proportionate to the total volume of milk. Thus, the total payment to each producer was 500 times $2.58, or $1,290. (Producers B, C, and D each had the same

[4] To simplify discussion, no deductions are included in this illustration.

volume as Producer A. Hence, they also each received $1,290 for their milk.)

Summary. The New York plan may be summed up as follows:

1. The plan provides that each distributor in a market pays prices for the values of milk based upon its uses throughout the entire market.

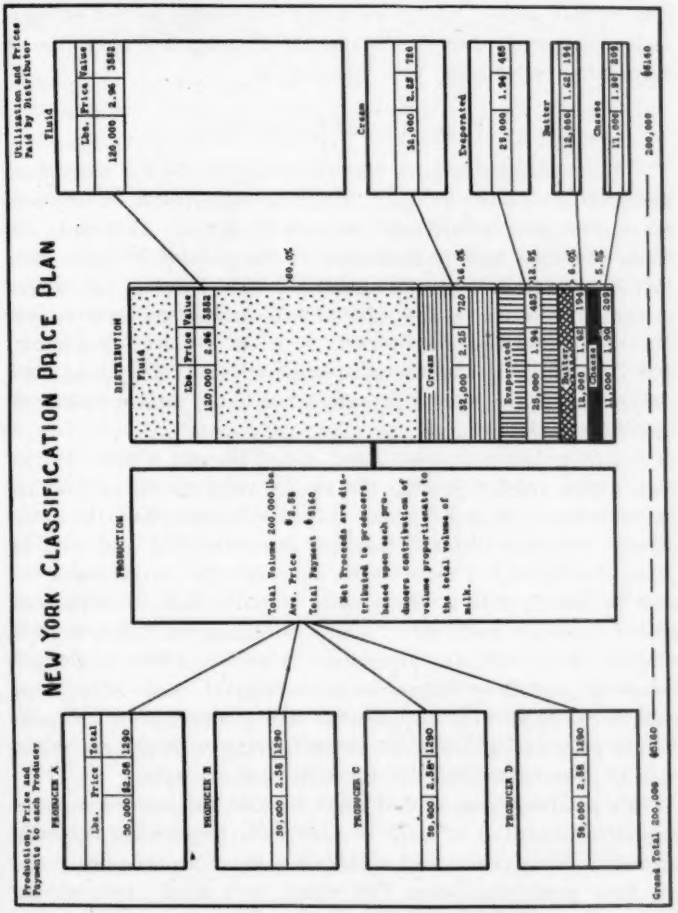

FIG. 5. Operation of New York classification price plan.

2. The plan treats all distributors in a market as a unit, instead of having as many different marketing units as there are distributors.

3. Payment of an average price to all dairymen penalizes producers having a relatively even production, to the benefit of those having a fluctuating production.

4. Raising and lowering an average price to regulate the flow of milk to meet market needs is a less flexible method of regulating production than the distribution of proceeds through use of a two-price policy along with this method.

BASIC-SURPLUS PRICE PLANS

The basic-surplus price plan is a structure for the purpose of distributing proceeds by means of two or more prices on the basis of market value contributed by each producer. As stated, the market value of milk in fluid uses, on the average, is higher than that for cream or for milk manufactured. There is the widest margin between the market value of milk in fluid and surplus uses during the least-surplus period, such as October, November, and December. During the most-surplus period, May, June, and July, there is the least difference between the market values of milk in its respective uses.

Each producer in a milkshed should be paid a price during each season which represents the market value of the milk which he contributes at this season. If all producers had the same seasonal variation in production, the average of fluid and surplus prices during each season would represent the market value of each producer's milk at this season. But the seasonal variations among dairymen result in variations in the market values of milk contributed by different producers. Since variations in market values are caused by differences in the market values of milk in fluid as compared with surplus uses, each producer should be paid a fluid price for that part of his milk going to fluid uses and a surplus price for that part of his milk used as surplus.

In practice, some method must be used for ascertaining the respective quantities of milk in fluid and surplus uses for each producer. This is done by means of a basic-surplus price plan, the basic production being that which most closely responds to fluid needs, and the surplus production being the surplus over fluid needs. A higher price can be paid for the higher value pro-

duction of each producer, known as "basic" volume, and an average surplus price, corresponding to the market value of the surplus, can be paid for each producer's surplus production.

THE PHILADELPHIA BASIC-SURPLUS PRICE PLAN

Under the Philadelphia basic-surplus price plan each producer receives two or more prices for milk, one price being paid for his "basic" milk, and the other prices for a surplus over this basic.

The "basic" volume for each producer in the Philadelphia milkshed is the average milk production of October, November, and December. Thus, in 1925, the directors of the Philadelphia producer's organization announced that October, November, and December of 1925 would be taken as the basic months on which to compute milk payments during 1926. Otherwise expressed, the basic milk for each farmer during the first nine months of 1926 would be equal to the amount of his average production during the last three months of 1925. All milk produced above this basic amount would be paid for as surplus.

Price Incentive for Even Production. Since the price for basic production is always higher than the prices for surplus over this volume, there is an incentive for each producer to maintain a production throughout the year more uniform than the natural seasonal production. The producer who has the least surplus gets the highest average price for his milk. Thus, suppose Producer A produced 50,000 pounds of which only 4,000 pounds were surplus (Figure 6). He would receive the highest average price for his milk, namely, an average of $2.67 per hundred pounds, as compared with $2.58, the average of all producers. Suppose Producer D produced 30,000 pounds over his basic production. Of this amount, 20,000 pounds would be Surplus I, and 10,000 pounds would be Surplus II. Since he would receive surplus prices for three-fifths of his total production, his average price would be only $2.38 per 100 pounds, as compared with $2.58, the average of all producers. Thus, each producer is paid a lower price for his share of surplus over basic milk while he is paid a higher price if he effects a more even production.

Summary. The Philadelphia plan may be summed up as follows:

1. The more uniform production resulting from paying a higher price to each producer for his "basic" volume than for his

surplus, results in a better adjustment of production to the consumption of milk.

2. The payment of a higher price for a "basic" production and a lower price for volume over this, more nearly approximates the value of each producer's market contribution than does the payment of an average price.

3. The basic-surplus price plan does not provide for selling milk so that each distributor in a market pays prices for the values of milk based upon its uses.

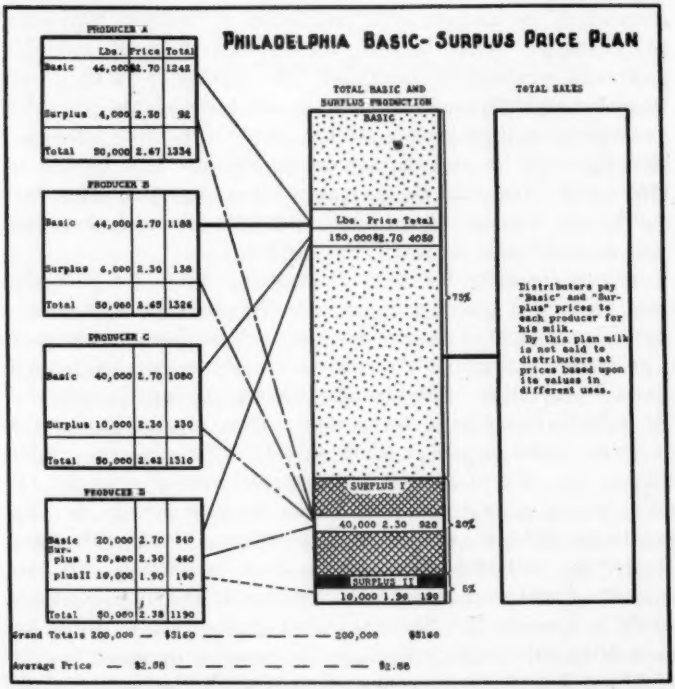
PHILADELPHIA BASIC- SURPLUS PRICE PLAN
PRODUCER A
Lbs. Price Total
Basic 44,000 2.70 1242
Surplus 4,000 2.30 92
Total 50,000 2.67 1334
PRODUCER B
Basic 44,000 2.70 1188
Surplus 6,000 2.30 138
Total 50,000 2.65 1326
PRODUCER C
Basic 40,000 2.70 1080
Surplus 10,000 2.30 230
Total 50,000 2.62 1310
PRODUCER D
Basic 20,000 2.70 540
Sur-plus I 20,000 2.30 460
plusII 10,000 1.90 190
Total 50,000 2.38 1190
TOTAL BASIC AND SURPLUS PRODUCTION
BASIC
Lbs. Price Total
150,000 2.70 4050
75%
SURPLUS I
40,000 2.30 920
20%
SURPLUS II
10,000 1.90 190
5%
TOTAL SALES
Distributors pay "Basic" and "Surplus" prices to each producer for his milk.
By this plan milk is not sold to distributors at prices based upon its values in different uses.
Grand Totals 200,000 — $5160 — — — — — 200,000 $5160
Average Price — $2.58 — — — — — — — $2.58

FIG. 6. Operation of Philadelphia basic surplus price plan. (Taken from Penn. State Col. Bul. 208.)

4. Lack of specific consideration of uses to which milk is put necessitates frequent modifications in the structure of the plan. Such frequent modifications tend to lessen confidence and stability within a market.

5. Lack of specific consideration of uses to which milk is put

tends to limit the operation of the plan to the fluid needs of a market, and to ignore the market uses of milk in the lower classes, such as milk used in ice cream.

EQUALIZING VALUE PRICE PLAN

Under the equalizing value (combination) price plan, milk is sold to each distributor for its market value in its different uses, and proceeds are returned to each producer on the basis of market value contributed. In developing this plan an attempt has been made to combine the sound elements of existing price plans with such new elements as seemed necessary in order to adhere to economic principles. This plan was put into operation in the Pittsburgh market October 1, 1928.

Sale of Milk to Distributors. The basis for sale of milk to distributors by the equalizing value price plan is "the sale of milk for each use at a price based upon its market value in each use." The different uses for milk are classified on a basis similar to the New York classification plan. Market prices for milk in fluid uses are arrived at in price conference of producers and distributors. Manufactured prices can be calculated on some formula, such as is used in the Baltimore or Philadelphia price plans. Where standards for grade and quality are recognized and enforced, the price for cream can be determined on a formula basis. At present, cream prices are arrived at in conference.

Illustration. Distributors in a market may pay prices and use milk in the way shown in Figure 7. Thus, of the total fluid (Class 1) sales, 50,000 pounds were used by Distributor A, 40,000 pounds were used by Distributor B, and 30,000 pounds by Distributor C. Distributor A used 10,000 pounds of the milk separated into cream; Distributor B used 24,000 pounds; and Distributor C used 30,000 pounds. Distributor A used no milk in butter; Distributor B used 6,000 pounds; and Distributor C used 10,000 pounds of the milk manufactured into butter. The market value of the milk purchased was $3,360 for fluid; $1,472 for cream; and $328 for butter, or a total of $5,160. Since the total volume was 200,000 pounds, this gave an average price of $2.58 per hundred pounds. Under the value price plan, however, proceeds are not distributed by an average pool price.

Two Prices to be Paid to Producers. Under the equalizing value price plan two prices are used to pay producers.

(1) A basic price which usually will be the fluid (Class 1) price as paid by distributors.

(2) An average surplus price which usually will be a weighted price of proceeds returned for surplus plus the proceeds returned for excess of fluid sales over farmers' basic quantity.

Thus, if the fluid price were $2.80 per hundred pounds, as shown in Figure 7, Producer A would receive this for 52,800 pounds, which was his basic volume, and Producer B would receive this for 65,280 pounds, which was his basic volume.

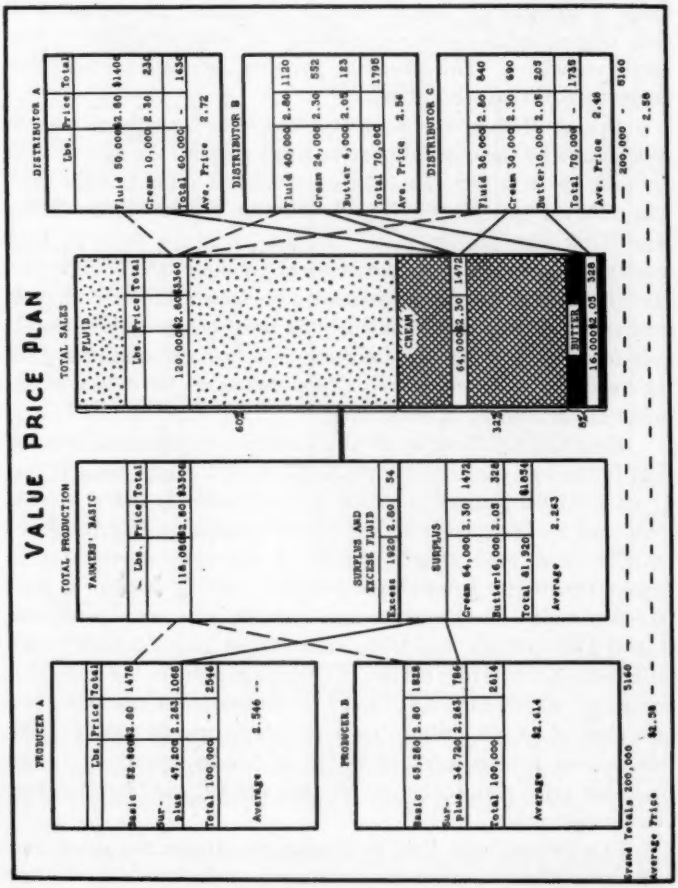

FIG. 7. Operation of the equalizing value price plan.

Summary. The equalizing value price plan may be summed up as follows:

1. Each distributor pays the market value for the milk which he receives, and each producer is paid for the market value of the milk which he contributes. This encourages the economic production and distribution of milk.

2. By its two-price basis of payment, this plan encourages a production which corresponds more closely to market sales. Use of this feature in conjunction with the flexible price feature in sale of milk to distributors, permits exercising direct control of production at all periods of the year. This is of special importance in preventing shortages or overproduction.

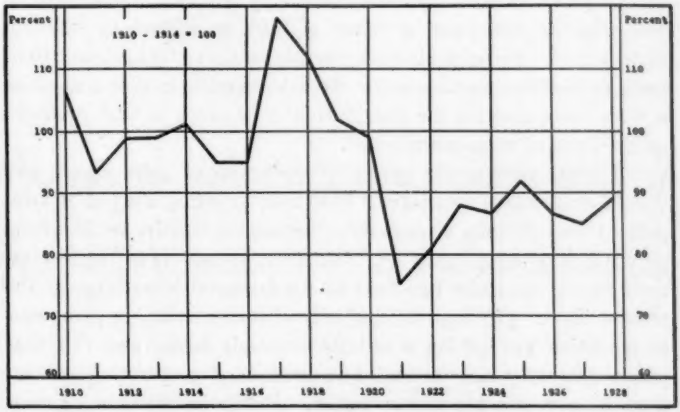

FIG. 8. Trend in purchasing power of farm products in terms of things farmers buy. [1910 to 1914 = 100]. (From Annals of the American Academy of Political and Social Science, March, 1929, p. 19. By Bureau of Agricultural Economics, U. S. D. A.)

3. By its two-price basis of payment, this plan works automatically from year to year in adjusting farmers' basic quantities to fluid sales. This obviates the necessity of frequent modifications in structure of the plan.

4. The plan is sufficiently broad in scope so that it can include those in a market using all surplus milk as well as those whose sales are largely of fluid milk.

5. The plan can be adapted to use in adjacent markets without penalizing or benefiting producer or distributor groups within these markets. This feature is of special importance in view of

probable consolidations of producers' associations in some markets which are now overlapping.

6. Use of two prices in paying each producer requires more calculations than does a one-price basis of payment.

7. Placing each producer's basic production so that it corresponds closely to his contribution to market value, makes it more necessary for him to watch changes in total market demand in its relation to total supply, if he is to realize the greatest returns for his product.

CONCLUSIONS

Some marketing plans fail to distinguish value as contributed by one producer from that contributed by another. Others fail to recognize the difference in values of milk as utilized by different distributors. No price plan can operate on a strictly economic basis until it includes provisions for the sale of milk to distributors on a value basis, and for the distribution of proceeds to each producer on the basis of value contributed.

During their entire period of operation of price plans, producers' cooperative associations have been enjoying the public sympathy which prevails when farm prices are low relative to consumers purchasing power (Figure 8). Constructive leaders of the associations should recognize two facts of fundamental importance at the present time: (1) that the majority of milk-marketing plans now in operation are not on a strictly economic basis; and (2) that public sympathy now extended to producers' cooperative associations is only of a temporary nature. Public indifference or antipathy to these associations is practically certain to follow when consumer purchasing power has its next decline. This may occur within the next year or two—possibly not for ten to fifteen years.

Social as well as economic progress of all groups interested in the dairy industry depends upon correct solution to problems of marketing milk. Much constructive work has been done through cooperative efforts of producers' associations and distributors. In some markets, consumers' groups have given their united support in improving conditions. The greatest progress at the present time lies in combining sound elements which these groups have initiated, with such additional elements as are necessary, in order to stabilize and otherwise promote the best interests of all concerned.

PAPERS IN MEDICINE AND PUBLIC HEALTH

EXTRACT FROM THE REPORT OF THE CHAIRMAN

The program of the Section in Medicine and Public Health included the reading of the paper listed below, in addition to those submitted for publication.

"The Inheritance of Monilethrix and Anhidrosis," by Elmer Roberts, University of Illinois, Urbana.

No business meeting was held and no chairman for 1929-1930 was elected.

MARIE A. HINRICHS, *Chairman.*

DECLINE OF DEATH RATE OF PULMONARY TUBERCULOSIS

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Hippocrates, who lived, practiced medicine, and wrote many masterpieces on medicinal subjects in the period of 400 B. C., made the statement that the disease which proved most dangerous and caused the most deaths was consumption. This statement remained true for 2,300 years. Within the last decade, consumption, or tuberculosis, as it is now more popularly called, has gradually declined from first to third and now to seventh place among the causes of death. The White Plague, the "King of Death," has surrendered its throne in favor of six other diseases, excepting in the age period of 20 to 40, where it still leads.

The specific cause of pulmonary tuberculosis was discovered in 1882, when Koch, a German physician, isolated the bacillus in his laboratory. It had not been isolated earlier by Koch or others because it does not take the ordinary stains that other bacilli do, on account of the coating of fat, or waxy capsule, around it.

In the past 25 years the death rate of tuberculosis in the United States has declined from 200 to 74 per 100,000 deaths. Even with such a wonderful decline, this one disease is still taking more than 5,000 human lives a year in Illinois.

This reduction in number of deaths has been made without a specific medicine, for there has not yet been found any specific cure for tuberculosis. We have no drug, no chemical that will kill the tubercle baccilli without destroying the tissues in which they are embedded. Here is a field for investigation and research, to find a specific cure for this dreaded disease.

The reduction has been made by earlier recognition and earlier diagnosis and by the time-tried treatment of rest, fresh air, and good food—building up the body of the patient—so that the work of the bacillus may be overcome. Were I asked to name the one most important cause for this reduction, I would unhesitatingly say, "Education." I mean education in its broadest terms:

(1) Education of the physicians, that they may learn to look for tuberculosis and to recognize it early. For in early discovery

is early recovery. Physicians generally agree that the treatment, until a specific medicinal treatment is found, is rest, fresh air, and good food, and that climate is a minor factor.

(2) Education of the public by the physicians in the knowledge that tuberculosis is preventable and curable, that it is not hereditary, but contagious, and that a person contracts the disease from other persons who have active cases of tuberculosis, or by drinking milk from tuberculous cows.

(3) Education that enables our people to live better, by working fewer hours, and enables them to live under more sanitary conditions. The idea must be universally accepted that fresh air, sunshine, and clean water are necessities of good health; that they are the best and least expensive remedies at our command; and that in tuberculosis, as in many other conditions, "common sense" is the best medicine.

(4) Educational campaigns relative to public health, under the direction of the national, state, and county tuberculosis associations, through all the schools, colleges, and universities, with particular attention to the diseases that are the major causes of death.

(5) A program of research promoted by societies, clubs, and institutional agencies, and particularly by the Illinois State Academy of Science, for it is the belief of many of our best authorities that the desired specific cure will be found by the chemists, who may learn how to dissolve the coating of wax and thus kill the bacillus.

Conclusion and recommendation. Since education, as defined in these terms, is the greatest factor in the decline of the death rate from pulmonary tuberculosis, and since further investigation is needed in order to discover a specific cure for this disease, it is recommended that the Illinois State Academy of Science take a part in promoting education in public health and encouraging research, to the end that the cure may be found.

PUBLIC HEALTH AND SEWAGE DISPOSAL

GUS H. RADEBAUGH
Manager, Urbana and Champaign Sanitary District.

In a recent survey made by the Izaak Walton League of America under the directorship of Dr. W. D. Hatfield, Superintendent of the Decatur sewage treatment plant, it was established that 60,000,000 people of the United States are served by sewer systems and that only 18,600,000, or 31 per cent, have some form of sewage treatment and that over 40,000,000 people in the United States are dumping untreated sewage into our country's inland and coastal waters. These amazing facts show conclusively that we in America have been making disease incubators out of our water courses.

The Roman Senate in the year 80 A. D. issued an order that it was necessary to save the water supply, as it was not only to be utilized for cleaning the city, but also for flushing the sewers. The collection of sewage, however, remained an unsolved problem until the nineteenth century. The London sewers were commenced early in the nineteenth century. Hamburg, Germany, laid out its sewerage system in 1842. Berlin's present system dates from 1860. Chicago in 1855 began the first general system in the United States.

The bath tub in its relation to modern plumbing is less than one hundred years old. Thirty-five years after the first comprehensive system of sewers was laid in the United States, attention was first directed to the objectionable condition produced by the discharge of sewage into American rivers. The year 1890 found men thinking about the importance of the practice of placing the untreated sewage into the water courses. Prof. A. N. Talbot of the University of Illinois designed one of the first Septic Tanks in 1897. Shortly after the development of methods to treat sewage, laws were approved making it possible for our people to take advantage of these scientific discoveries.

ILLINOIS LAWS REGULATING SANITARY DISTRICTS

Harry F. Ferguson, Chief Sanitary Engineer of the Illinois Department of Public Health, in his pamphlet on Sanitary Dis-

tricts in Illinois, lists three laws in force in this state regulating the formation and operation of sanitary districts, primarily for the disposal of sewage. Two of these laws are special; one controls the Sanitary District of Chicago, approved 1889, and the other the North Shore Sanitary District, approved 1911. A sanitary district law of general application was passed by the legislature in 1917 and is popularly known as the law of 1917. It was amended by the legislature in 1923 and 1927. Sixteen municipalities have taken advantage of this act and have plants in operation or under construction. They are as follows:

Bloomington-Normal	Peoria
Decatur	Hinsdale
Downers Grove	Galesburg
Elgin	Matteson
Aurora	Rockford
Springfield	Urbana-Champaign
Wheaton	Taylorville
Clinton	DeKalb

One or two other cities at the present time are building plants under the local improvement act.

In Bulletin 20, State Water Survey, A. M. Buswell, Chief, a preliminary notice of a survey of the sources of pollution of the streams of Illinois shows that a total of 134 municipalities are dumping untreated sewage in the streams of the state, that 70 towns include treatment with some sort of settling tanks, and that 59 towns include treatment with settling tanks plus additional treatment units. This information indicates that Illinois has considerable more work to do in freeing her water courses from pollution and reducing sickness directly chargeable to this deplorable condition. In the Forty-third Annual Report of the Illinois Society of Engineers, page 83, will be found a tabulation of data on Illinois Sewage Treatment Plants, compiled by Harry F. Ferguson with the assistance of A. F. Dappert and C. E. Schwob, members of his staff. This tabulation is very complete and permits careful study of capacity and design used by our various cities.

POLLUTED STREAMS STRIKE BACK

An inspection of some of our streams will reveal a conglomeration of filth, sewage, and a breeding place for disease. Hundreds of recorded cases in this country have established polluted water as the cause of community epidemics.

It is established that ninety-nine per cent of all infections are taken into the body through the mouth. They reach the mouth in water and food, on fingers and dust. Infection may enter the body through (1) the respiratory tract, (2) the digestive tract, (3) the skin.

Dr. Raymond Pearl reports that functional disturbances of the alimentary tract and associated organs are responsible in the United States for 334.9 deaths in each 1,000, the remainder being due to other causes. It is clear that an opportunity for retarding death rates lies in the elimination and control of the causes of disease of the alimentary tract.

Does the polluted stream strike back? It does and in several ways: Its water is unfit for drinking and bathing. Diseases are carried from it by flies. Cattle drink water from and wade in polluted streams, perhaps unknown to the farmer, but known to the city administration that is permitting such pollution, thus contaminating the milk supply.

SICKNESS AND DEATH EXPENDITURES

Dr. Louis I. Dublin, Statistician of the Metropolitan Life Insurance Company, in his article on "The Economics of World Health" printed in Harper's Monthly, November, 1926, gave a few figures that tell a story of waste in human life that we as a people must seriously recognize.

(1) Nineteen dollars per capita average expenditure for medical and nursing care in illness per year, representing a cost of more than a billion dollars per year.

(2) One hundred twenty thousand babies die from preventable causes during the first year of life. Capital value of boys, $9,000; girls, $4,600. Preventable infant mortality represents a capital cost of three-quarters of a billion dollars per year.

(3) Thirty thousand young men and women, 25 to 29 years of age, die each year from preventable causes. Loss about three-quarters of a billion dollars.

(4) Six billion of dollars can be saved each year in accepting modern preventive medicine and public health measures.

EDUCATIONAL EXPENDITURE

National expenditure for education in the public school system of the United States is $1,588,671,000, or a per capita cost of $14.70 on a population basis of 110,000,000.

This shows the amazing fact that we spend $4.30 per capita more for careless and incorrect living, disregard for health rules and measures, than we spend on our school system. This deplorable condition is certainly chargeable to the "I don't care" attitude of a people who by the necessity of existence finally will accept the discoveries of the scientists and apply them to every community and every individual.

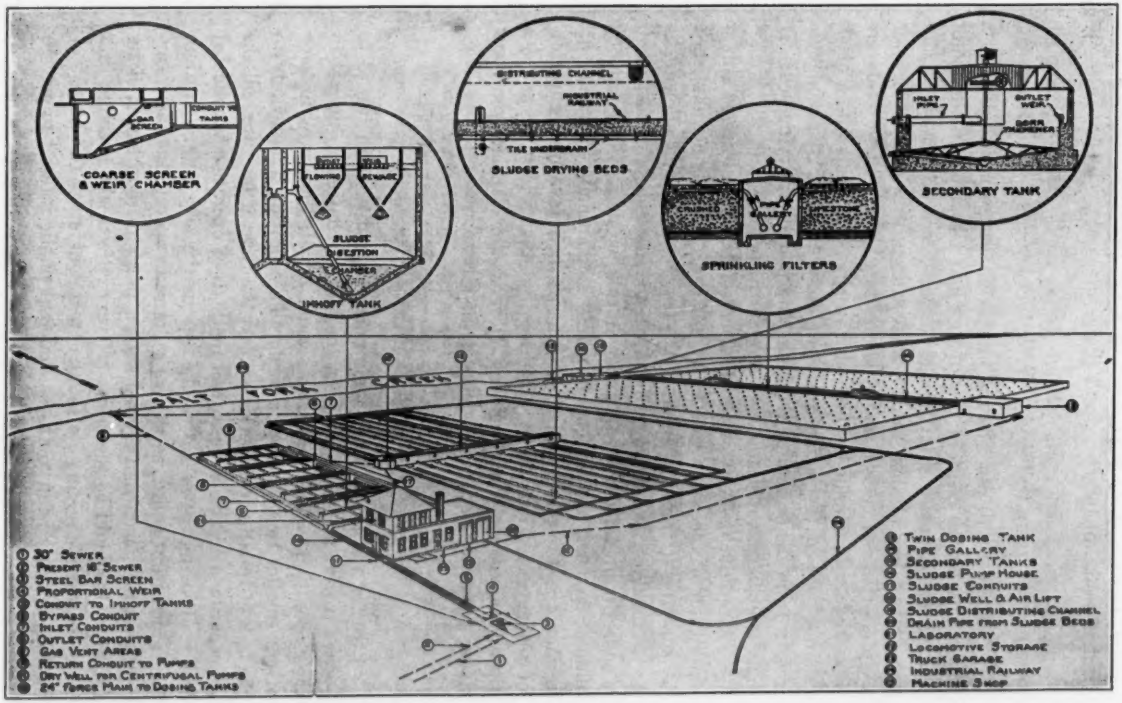
MUNICIPAL EXPENDITURES

A city and its municipal government makes it possible for its citizenry to unite and do things which they cannot do as individuals. Today the city, through the taxes received, protects life and property, safeguards health, protects from fire, builds, cleans, and lights the streets, helps to build county roads and bridges, maintains free employment bureaus, educates the children, offers library facilities, give opportunities for recreation in parks, administers justice, supplies nurses, health officers, and hospital service, inspects the food and water supply, the gas and electricity for lights and domestic services, and maintains storm drains and sewerage systems. This service costs money, a lot of money as a lump sum, but on a per capita basis surprisingly little. In a city of 300,000 all these blessings of community enjoyment cost only $16.62 per capita per year, which is $2.38 less than is spent on illness.

TREATMENT OF SEWAGE

Every state and municipal official and every citizen should encourage and demand healthful environment for community life. Properly designed and managed sewage treatment plants must be a part of every community. They should and must be as common to our towns as the fire department and the city building. In the treatment of sewage another safeguard is established in the protection of the Public Health.

The treatment of sewage includes the destruction of pathogenic bacteria, the elimination of offensive odors, and the removal of solid organic matter which would absorb the oxygen from the water if dumped into a stream. The modern plant thus prevents the destruction of aquatic life in the stream, and disposes of the liquid portion in such a way that nature can complete its purification. The several methods used in the design of American disposal plants are as follows: screening, sedimentation, septic


COARSE SCREEN & WEIR CHAMBER
IMHOFF TANK
SLUDGE DRYING BEDS
SPRINKLING FILTERS
SECONDARY TANK
SALT TOWN CREEK
30" Sewer
Present 18" Sewer
Steel Bar Screen
Proportional Weir
Conduit to Imhoff Tanks
Bypass Conduit
Inlet Conduits
Outlet Conduits
Gas Vent Areas
Return Conduit to Pumps
Dry Well for Centrifugal Pumps
24" Force Main to Dosing Tanks
Twin Dosing Tank
Pipe Gallery
Secondary Tanks
Sludge Pump House
Sludge Conduits
Sludge Well & Air Lift
Sludge Distributing Channel
Drain Pipe from Sludge Beds
Laboratory
Locomotive Storage
Truck Garage
Industrial Railway
Machine Shop

tanks, contact beds, sand beds, trickling filters, activated sludge, Imhoff tanks, disinfection, and sludge disposal.

URBANA-CHAMPAIGN PLANT

Briefly I will describe the process of sewage purification in a plant serving the cities of Champaign and Urbana. In this plant the sewage is passed first through a coarse screen, then flows into two-story tanks (Imhoff tanks) 33 feet deep, in which the heavier solids settle and collect in the lower story, where these solids are attacked by an aërobic bacteria which reduce the solids into a black humus. When the solids are completely digested, the sludge is drawn from the bottom of the tanks and placed on drying beds. It may later be removed and used as a fertilizer.

After the removal of the heavier solids, the sewage is still a milky liquid and must be further purified. This is accomplished by spraying it through nozzles (like lawn sprays) and allowing it to trickle down through a bed of broken stones about ten feet deep. The bed is provided with an under-draining system. An enormous number and a great variety of plants and animals soon take up residence in these rock beds to engage in their favorite occupation of scavengers. This water after leaving the filters is to pass through a secondary settling tank, Dorr tractor clarifier type (now under construction), before joining the stream.

NEGLECT IN OPERATION

One of the tragedies of community expenditures in regard to sewage treatment plants has been the lack of continued interest in their operation. An investigation would reveal, I am sure, in some of our smaller communities, a deplorable condition due entirely to the lack of intelligent supervision. At the time of building, all the information available as to correct methods of operation is collected and studied, but after a few changes in the city administration, the information is lost, as well as a desire to operate the plant correctly. A city that has followed such a program soon learns of its futility. It should be the desire of every citizen who is living in a town that is not giving its sewage treatment units the benefit of intelligent supervision to arouse sufficient public interest to get the condition improved.

RESPONSIBILITY

The engineering and chemical professions have an important obligation to perform for society in the design and construction of the modern sewage treatment plant. These two great forces must have the interest of each community at heart. For the sake of continued public acceptance of sanitary science, only tried methods and design should be considered. The taxpayer in the end will be the judge of the work.

Biologists, chemists, and engineers have given to civilization a way to care of its wastes. The pollution problem is now in the hands of the citizens, and any delay in adopting proper methods for the treatment of municipal and industrial refuse is directly chargeable to you and me as taxpayers in our respective communities. The question of proper sewage treatment is a challenge to the pride of every community. As Dr. Henry Baldwin Ward, National President of the Izaak Walton League of America, puts it: "Sanitation means civilization, not only success, but comfort and happiness, and even more than that, it means existence. The penalty of ignorance and carelessness comes in the form of disease, death, and destruction."

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Preventive Medicine and Hygiene—Rosenau.

EPILEPSY, ITS DIET AND DRUG RELATIONS

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Since the problem of the etiology of epilepsy remains so obscure that we cannot even estimate the rôle which endogenous and exogenous factors play, there is a certain justification in following up mere conjectures in order to prove or disprove their merits. The fact that fasting produces a cessation or at least a diminution in the number of seizures in many cases was brought out through the conjecture of an osteopath in 1921. The ketogenic, or acid-producing, diet was worked out afterward and was calculated to cause changes in the body of the epileptic similar to those produced during starvation.

During fasting there is a distinct amelioration of symptoms in the epileptic, with a reduction in the alkali reserve of the body, a decrease in blood sugar, an increase in uric acid and in the hydrogen ion concentration of the blood, as well as an increase in excretion of ammonia and a titratable acidity of the urine. Through the administration of the ketogenic diet similar results are produced.

The ketogenic diet consists of a normal amount of proteins, a very much reduced quantity of sugar and starches, and an excess of fats in the form of rich cream, butter, mayonnaise, bacon, oil, etc. The fat is only incompletely broken up in the absence of carbohydrates, and intermediary products of digestion are formed belonging to the acetone groups, which are highly acid in reaction. It is thought that this production of acid during digestion is the essential thing in obtaining results, although there are probably some additional factors still unknown.

The ketogenic diet must be estimated and adjusted for each individual case, every patient having his own peculiar metabolism. It is interesting to note how much difference there is in the requirements for acid production in the various patients. While one patient is markedly benefitted by a diet producing only a minor degree of acidity, another patient needs a very high degree of acid production. This peculiarity is not constant in the same patient

but has shown a good deal of variation at certain times. The same is true in the variability of acid required in different patients at various times in order to cause a change in the hydrogen ion concentration of the body fluids. It might be stated here that this difference in acid requirement in various individuals is one reason for the conflicting results obtained in this method of treatment.

The administration of acids as well as acid-producing drugs has proved beneficial, but their action is much more transitory than the ketogenic diet and is, therefore, of value largely as a supplement to the diet. It cannot be denied that in fasting or in the administration of the ketogenic diet we have found for the first time a method to control epileptic seizures without the use of depressing drugs. Whether the result is obtained because of the dehydration of the body or because of the anaesthetic action produced by the acetone bodies, or on account of the neutralizing effect upon the excessive alkalinity in the body, is as yet undetermined. One must also take into consideration the possibility of detoxifying and stabilizing process of the body produced by the ketogenic diet.

Our work this last year has been carried on at the Chicago State Hospital in the cottage for female epileptics with eight inmates. In the course of time we found that about forty per cent of the total number of patients were amenable to the dietary treatment. Of the forty per cent about one-half of them showed a marked improvement and the other half a moderate improvement.

Patients with marked mental deterioration were found to be unsuitable, also those with organic brain defects or with physical disease. Patients who were markedly underweight or those with pulmonary or renal disease were rejected.

We have had a few patients who were exceedingly interesting. One woman, forty-five years old, for twenty-eight years an inmate at the institution, has had daily major convulsions since infancy. She had a surprisingly small degree of mental enfeeblement and was physically in a good condition. Within less than a week after the administration of the ketogenic diet, her convulsions ceased. Her physical appearance changed a good deal, her complexion became clearer, her eyes brighter, her walk more elastic, and her interest in her surroundings more keen. She had not a single convulsion for several weeks until she broke her promise and succumbed to the temptation of a piece of candy; then she had a number of severe convulsions. We again put her on a diet, and the

seizures stopped until we made a little change in the diet which again caused some convulsions. This patient needed a highly restricted diet.

Another patient, about twenty-five years old, showed a cessation of convulsions while on a very moderate ketogenic diet. The restriction of carbohydrates was hardly large enough to cause acetone bodies to appear in the urine, but yet there was a marked improvement. When the diet was discontinued, she had from two to sixteen convulsions daily. The improvement in physical appearance was the first change noticeable, the greater mental alertness followed, and a little later the influence on the number as well as on the severity of convulsions could be demonstrated.

The cooperation of the patient is essential, since even a small error in diet will upset the results obtained after weeks of treatment.

In conclusion it might be stated that the ketogenic diet is not a cure-all in epilepsy, that it is of value only where constant individual observation by a physician is possible. We have found, however, a basis of attack on the disease and a starting point for a new direction of research.

THE EFFECT OF ROENTGEN RAYS OF DEFINITE WAVE LENGTHS AND "R" UNITS UPON NORMAL OVARIAN TISSUE AND OVA

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Since Roentgen in 1895 discovered a new radiation which he called X-ray, there has been a steady advance in knowledge of this science brought about by constant research and use of X-rays, which are now more properly called roentgen rays.

As early as 1897 Destot (6) did work with irradiation on the skin, and Bergonie in 1906 (1) on the testes of rats. Regaud and his collaborators in 1912 (8) studied the effect of soft roentgen rays upon the skin, stomach, and intestinal tract—all showing non-healing ulcers.

Although the equipment was crude, the medical profession put this new science to practical use in these early days. In 1914 a distinct advance was made by the discovery of the hot filament tube by Coolidge (5). Since 1917 further improvements in the development of roentgen transformers of mechanical and kenetron rectification have placed in the hands of the radiologist a new type of radiation of very short wave length.

The development of instruments for the measurement of wave length, and the simplified methods of measurement such as the Duane method, published by the senior author (2), and a standard "r" unit are other distinct advancements in radiological instruments and methods of precision, making it possible for the work of the roentgenologist to be accurate and intelligible.

Quoting G. L. Clark (3): "There is no question but that greater effectiveness in the treatment will come only with adequate scientific knowledge and with the skilled measurement of dosage in terms of X-ray spectra, the laws of absorption, and the establishment of ionization phenomena. To this end a close research co-operation between physicians and surgeons, physicists, colloidal chemists, and the manufacturers of equipment is absolutely essential."

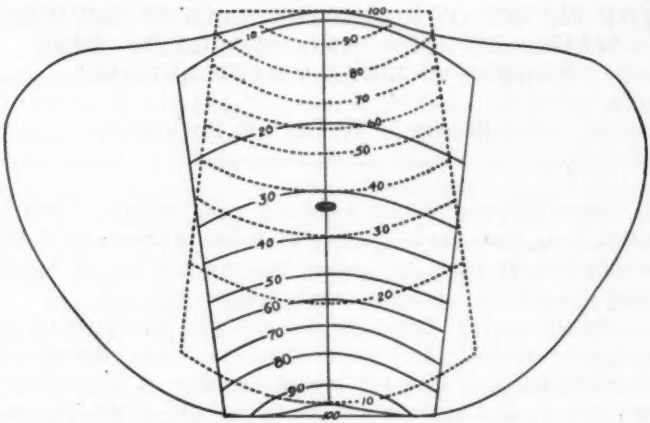


FIG. 1. Curves for Case No. 2365, rayed through two ports. A. P., 18 cm. Transverse, 24 cm. Lat., 30 cm.

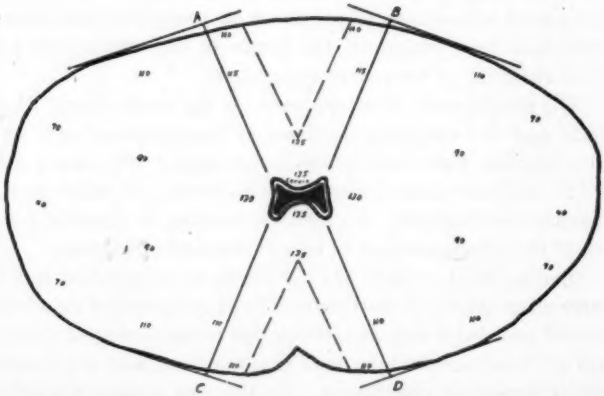


FIG. 2. Anatomical cross-section chart to size of patient, showing number of fields, angle of incidence, tumor area, and depth dose percentages, with four skin portals. Filter ½ Cu, 2 Al. K. V., 200. S. T. D., 50 cm. Erythema, 300 Ma. Min. Tumor Int., 135%. Skin Int., 75%; 225 Ma. Min. (Cross-section No. 9.)

Atoms are solar systems of electrons rotating in orbits. Position of the electrons is wholly indetermined. Tissue cells are composed of innumerable atoms of different kinds arranged to form a complex structure. How do roentgen rays produce their effect? Compton (4) shows how a beam of rays striking an electron drives it in a direction depending upon the angle at which the electron is struck. If it is straight, the electron is driven in the same

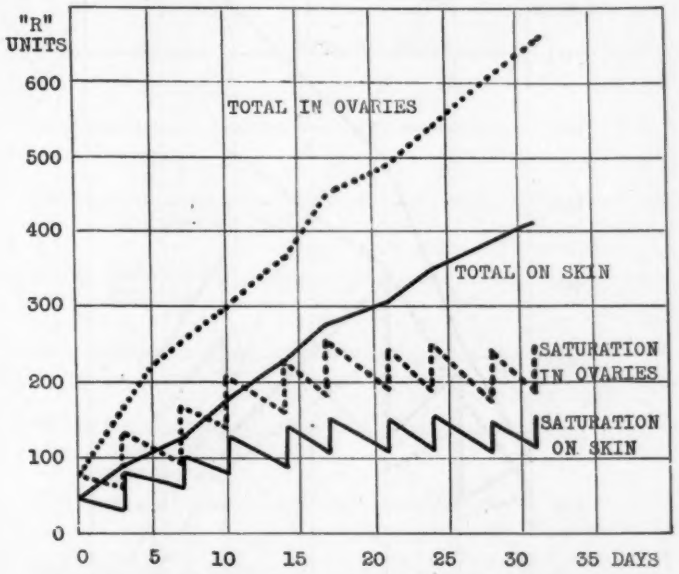


FIG. 3. Plan of treatment of case No. 1447, treated two times per week, beginning April 5 and ending May 6. Four ports. P. K. V., 200,000. M. A., 5. S. T. D., 50 cm. Filter ¾ Cu, 1 Al. Int., 9.12 "R" per min. A. U., 0.178. Port, 8 cm. Surface, 10 cm. Depth dose, A. P. 40%; P. A., 40%.

direction from which the beam of ray comes; if a glancing blow, the electron is driven at an angle from the beam.

What takes place when these complex cells, differing in chemistry, structure, function, normal or pathological and in stages of development or fully developed, are bombarded with rays of long or short wave length, little or great penetrating power, of small, medium, or large dose?

All these questions are of extreme importance and interest to the scientist, the radiologist, and of vital importance to the sufferer of malignant disease curable by radiation when properly applied. With the aid of several lantern slides of histological sections of ovaries having received rays of different wave length and dosage, I will endeavor to show the results of such treatment, but first

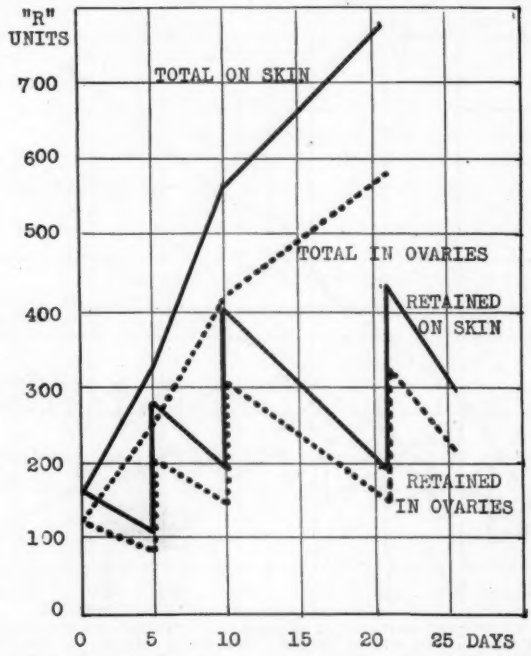


FIG. 4. Chart of rabbit No. 5. Treatment began February 27. Animal killed March 24. P. K. V., 180,000. M. A., 5. Filter, ½ Cu, 1 Al. S. T. D., 50 cm. A. U., 0.21. Int., 11 "R" per min. A. P., 2.5 cm. Depth dose 74.5%.

it is desirable to show a simplified method of determining and charting the amount of irradiation received by the skin and structures beneath. Pfahler (8) and Weatherwax and Widmann (10) have been successful in working out a system of curves and charts for calculating the dose, penetration, and retention. These charts are used for permanent records. Figure 1 shows the method of calculating the percentage of depth dose for two-port entry.

Figure 2 shows a cross-section treatment given in four ports, the numerals representing the percentage of depth dose. Figure 3 is a chart for the treatment of one of our patients. Figure 4 and 5

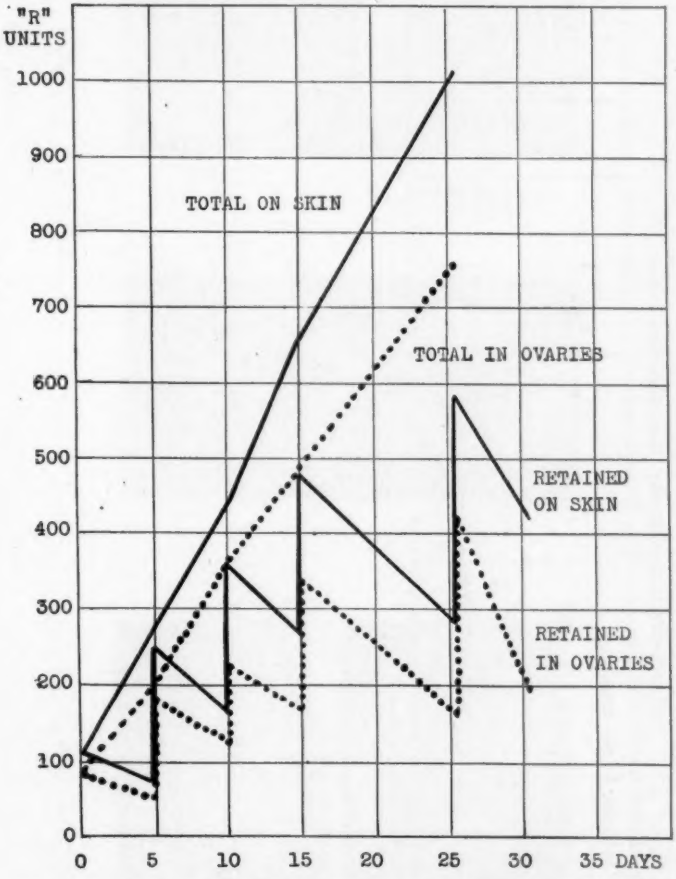


FIG. 5. Chart of rabbit No. 6. Treatment began February 22. Animal killed March 24. First treatment was P. A., 5.5 cm.; depth dose 56%. Other treatments same as for rabbit No. 5.

are similar charts showing treatments of two rabbits. We are using "r" units in place of milliampere-minutes as originally used by the authors referred to above.

TABLE I—1928, RABBITS, BUCHER CLINIC, CHAMPAIGN, ILLINOIS.

No.	Dates and "r" units of treatment.						Total "r" units.	Killed.	A.U.	P.K.V.	MA.	Filter.		Distance.
	2-22	2-27	3-3	3-8	3-19	4-16						Cu.	Al.	
1	----------	----------	----------	a289.75	----------	----------	289.75	3-22	0.22	180	5	½	1	50 cm.
2	a165	b165	a165	----------	----------	----------	495.00	3-12	0.21	180	5	½	1	50 cm.
3	----------	a165	a165	a221.84	----------	----------	551.84	3-19	0.21	180	5	½	1	50 cm.
4	b110	a165	a165	a220.00	----------	----------	660.00	3-19	0.21	180	5	½	1	50 cm.
5	----------	a165	a165	a221.84	a230.63	----------	782.47	3-24	0.21	180	5	½	1	50 cm.
6	b110	a165	a165	a220.00	a353.65	----------	1,013.65	3-24	0.21	180	5	½	1	50 cm.
7	----------	----------	----------	----------	----------	a144.00	144.00	4.25	0.20	200	5	1	1	50 cm.

Depth of tissue and ovary: Back, 5.5 cm.; abdomen, 2.5 cm.
a. Rayed through the abdomen.
b Rayed through the back.
These rabbits were about the same size.

FIG. 6.

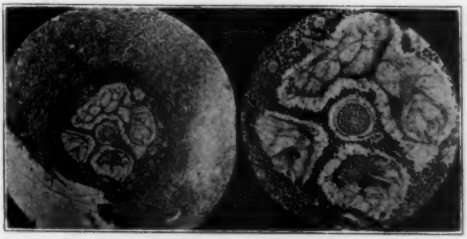


FIG. 7.

FIG. 8.

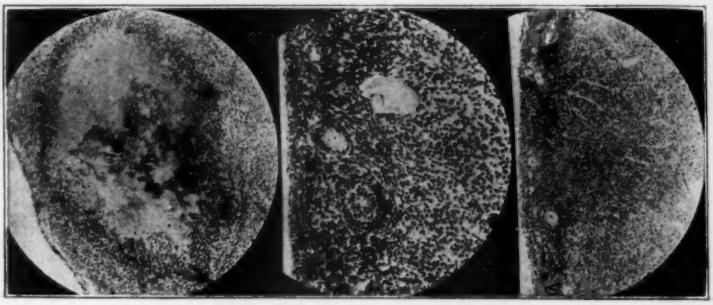
FIGS. 6-8. Photomicrographs of unrayed normal ovary, low power at left and high power at right.

GROSS APPEARANCE

The rayed ovaries were much smaller in size than the unrayed. This decrease in size was progressive from the normal, to the ovaries receiving the smaller dose, to the ovaries receiving the larger dose of roentgen rays. The shrinking was to the extent of about one-third that of the normal ovary. (See Fig. 14.)

HISTOLOGY

Microscopically, in the normal ovary we have a mature corpus luteum and ovum ready to leave the corpus luteum (Fig. 6). On the opposite side of the same ovary we have an ovum in the late



A. B. C.

FIG. 9. Sections of a rabbit's ovary receiving 290 "r" units.

stage of development (Fig. 7). The cells around the corpus luteum are formed in layers, the corpus luteum itself is well formed, and the ovum is freeing itself from its attachments. In no case were we able to find an ovum developed to this extent in the ovaries receiving rayings.

In studying the changes in the ovaries receiving roentgen raying, we see that the stroma is atrophied. This causes a closer arrangement of the cells, which becomes more apparent as the "r" units of rayings are increased.

Figure 9 shows three cross-sections of an ovary receiving 290 "r" units of radiation. Part A shows a nearly developed corpus luteum and ovum with complete disarrangement of the cells forming a fairly homogeneous mass. Part B shows a developing ovum

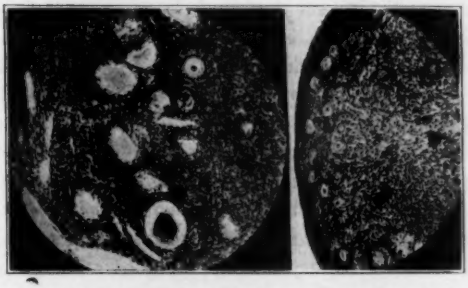


FIG. 10. Treated with 495 "r" units.

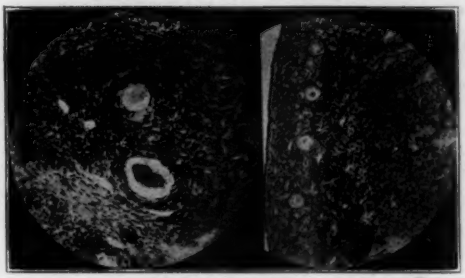
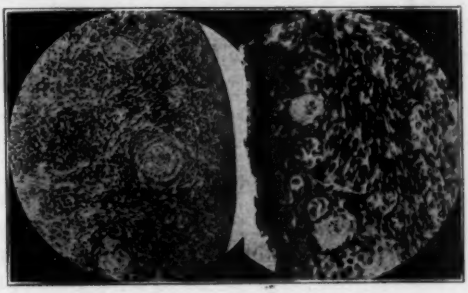


FIG. 11. Treated with 552 "r" units.



A. B.

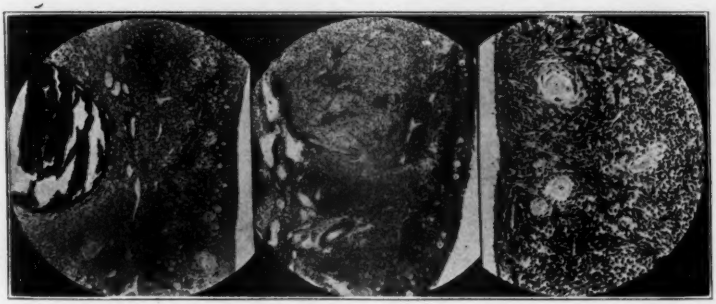
FIG. 12. *A*, treated with 660 "r" units; *B*, with 782 "r" units.

completely broken down, with the atrium filled with blood. Part C shows the close arrangement of the cells of the ovarian structure.

Figure 10 shows two sections of an ovary from a rabbit receiving 495 "r" units divided into three doses. More of the developing ova are broken down than were noticed in sections from the rabbit receiving less raying in a single dose, but the small developing ova are not so much disintegrated.

Figure 11, which is from a rabbit receiving 552 "r" units, in divided doses, shows that the medium-sized developing ova are destroyed, and that the nuclei of the young ova are disarranged. There is also evident a very close packing of cells in this ovary.

Figure 12A is a section from a rabbit receiving 660 "r" units in divided doses, the developing ova being broken down.



A. B. C.

FIG. 13. *A* and *B*, receiving 782 "r" units; *C*, 1013 "r" units.

Figures 12B, 13A, and 13B are sections from the ovary of a rabbit receiving 782 "r" units. In these sections, where the ova were far enough advanced in development to study the changes, the nucleus of the ovum is invariably disarranged. This would indicate sterility. Figure 13A shows a large blood clot in the atrium. Figure 13B shows very closely packed ovarian cells with few primordial ova in the germinal epithelium which are apparently being squeezed out of existence. Figure 13C is a section of an ovary from a rabbit receiving 1013 "r" units, showing broken down ova with germinal epithelium, but almost no primordial ova.

What would a micro-motion picture of irradiation of this kind show if it were possible to carry it on for a month with the rayed tissue in the body in its normal position? It is hoped that every

person in America interested in this subject will have an opportunity to see the wonderful film reproductions of Doctor Canti. Some of you I am sure have had this opportunity.

Quoting Ewing (7): "Ultimate knowledge of the mode of action of radiation still eludes our grasp." We can understand, however, that irradiating any cells means the bombarding of the electrons within the atoms. This in turn produces its effect upon the structural arrangement.

FIG. 14. Gross appearance of rabbit ovaries: *a*, unrayed normal; *b*, small amount of raying; *c* and *d*, receiving larger amounts respectively

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AXIAL DUPLICATION PRODUCED IN LOWER VERTEBRATES BY EARLY EXPOSURE TO ULTRAVIOLET RADIATION

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By means of early exposures of developing embryos of the chick and the salt-water minnow, *Fundulus heteroclitus,* it has been possible to induce the formation of axial duplications.

In the chick, it has been possible to produce only partial duplication, as for example, duplication in the region of the developing heart, or in the posterior somite region. Since the egg of the hen is already fertilized and the axis determined before laying, it has not been possible to induce the formation of double-headed forms by the means employed. The egg of the hen was removed from the incubator at various periods during development, and a window cut in the shell and shell membrane. The developing embryo was then exposed directly to the radiation from a quartz mercury-vapor arc, for short periods of time. The egg was again sealed, and replaced in the incubator and allowed to develop to the 72-hour stage, at which time it was compared to normal control eggs. Controls in each experiment were kept as follows: unradiated, unoperated controls; unradiated, operated controls; and controls radiated through the intact shell. Of the total number of malformations produced in this way, about 3 per cent of the embryos showed axial duplication of parts, most of them in the neural tube region.

A higher percentage of twin production was possible in *Fundulus heteroclitus.* The eggs of this fish were exposed at various intervals following fertilization. Since the eggs were obtained from the female fish by "stripping" and then fertilized in a dry dish and then washed free of excess sperm, it was possible to obtain embryos in which the axes had not yet been determined. By exposure to ultraviolet radiation just before the two-celled stage was reached, from 0.2 per cent to 12.5 per cent twinning was obtained in various experiments. Of exposures made at 12 to 96 minutes after fertilization, 12 out of 20 experiments showed twinned

embryos. There were varying degrees of twinning in the anterior region. Two completely formed heads, with a common body, appeared in some cases. In other experiments, typical autosite-parasite twins were formed. In these, one axis appeared to grow at the expense of the other, and the result was that there was formed one normal head, and a partly developed head appearing either laterally or ventrally to the normal head. In a few cases, the embryos were small, and both were abnormal. Such fish did not hatch. Double-headed fish, as described above, may possess either one or two hearts. In the latter case, the heart rhythms vary.

Twinning in the posterior region of the embryo was produced when exposures were made at a later stage of development, namely, when the germ ring is descending over the egg, at about twenty-five to twenty-eight hours after fertilization. A bifid tail is formed by exposures made during this period, but sometimes embryos which give promise of cauda bifida, later produce but a single, much-distorted tail, indicating a fusion of the temporarily separate growing regions.

For a review of the literature on twinning, the reader is referred to studies by H. H. Newman and by C. R. Stockard, to which references may be found in my paper on *"Fundulus Heteroclitus and Ultraviolet Radiation,"* appearing in Jour. Morph. and Physiol., Vol. 41, No. 1, 1925.

AN APPARATUS FOR THE ESTIMATION OF SURFACE TENSION IN BIOLOGICAL FLUIDS

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During a study conducted on energy transformations in biological systems, a necessity arose for a method of rapid estimation of surface tension without removal of the fluid to be measured from its container. Advantage was taken of the fact that the gas-liquid interfacial tension of a system will govern the volume of a bubble of gas formed at an orifice within the liquid. By measuring the number of bubbles formed per unit volume of gas, the volume of one bubble can be calculated, and this bubble volume is related to the surface tension by the formula:

$$Sx = \frac{Vw\ D\ Sw}{Vx}$$

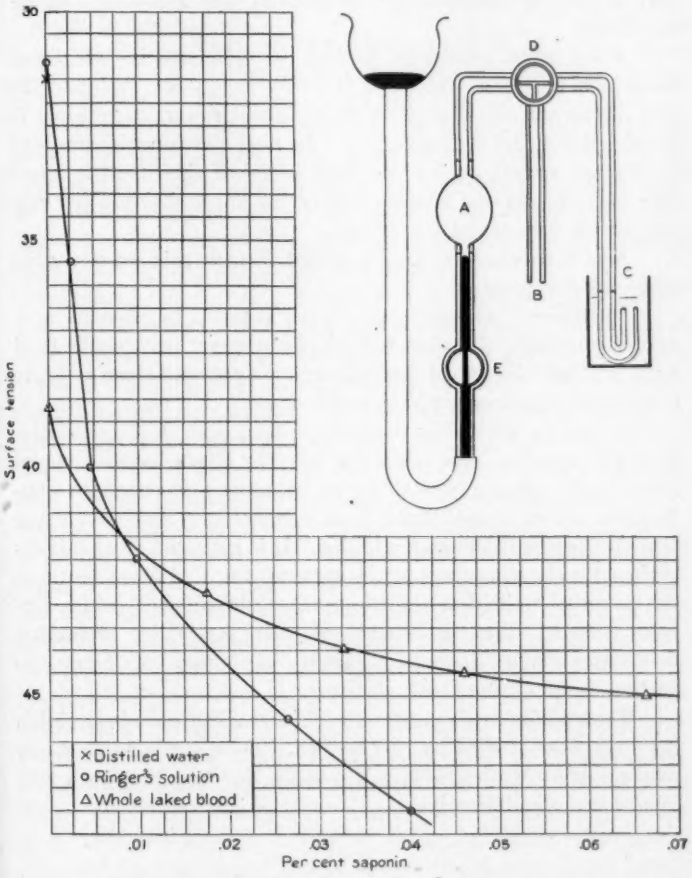
where Sx is the surface tension of the unknown; Sw, the surface tension of water; Vw, the bubble volume of water; Vx, the bubble volume of the unknown; and D, the density.

The apparatus is shown in the figure, and its construction from a three-way, T-shaped, 1.5-mm. bore, capillary stop-cock is obvious from the diagram. The two continuous arms are bent parallel and in the same plane as the side arm; in arm *A* a bulb of about 1 cc. capacity is blown, and the opening of this arm communicates through a one-way stop-cock to a leveling bulb which is attached to the apparatus by a rubber tube.

Arm *C* is doubled back upon itself one centimeter from the end, and the office is made smooth and round by fire polishing. Three marks are made on the apparatus, one below and one above the bulb in arm *A*, and one on arm *C*, two centimeters above the bend. The leveling bulb is filled with mercury.

Determination: First, *E* is turned so that *B* and *C* communicate, and *C* is immersed in triple-distilled water until the orifice of *C* is submerged and the water has risen to the mark on *C*. Then *E* is turned so that *A* and *B* communicate, and the mercury is allowed to rise to the lower mark on arm *A*. Next, the one-way stop-cock *D* is closed, and *E* is turned so that *A* and *C* communicate. Then *D* is partially opened, and the air in the bulb

is slowly displaced through the water, so that about two bubbles are formed per second. The bubbles are counted, and when the mercury reaches the upper mark, *D* is closed, an estimation being made of the fraction of the bubble usually remaining in the orifice.



To duplicate the determination, *E* is turned so that *B* and *C* communicate, when the water returns to the mark. Then *A* and *B* are made to communicate, the leveling bulb is lowered while the return of the level of mercury to the lower mark is controlled by *D*.

This serves to calibrate the apparatus. The entire procedure is then repeated for the unknown.

For calculation of the surface tension by the formula given above, the number of bubbles formed in water and the number formed in the unknown are substituted for Vw and Vx, respectively.

When fluids containing proteins or other colloids are being measured, it is important that the rate of bubble evolution be slow. The rate will depend on the fluid under examination, and it is advisable to try different rates. In fluid like blood serum, one bubble per second appears to afford sufficient time for the interface to come into equilibrium; in pure liquid one may use any rate compatible with accurate counting.

Arm *C* should be cleaned with hot chromic acid whenever the stop-cock *E* is greased.

Discussion. This apparatus is not intended to supplant more accurate methods of surface tension measurement, but is submitted because it has been found useful in following certain changes where a moderate degree of accuracy was desired.

Curves are shown for titration of blood and of Ringer's solution with saponin. The blood was laked by alternate freezing and thawing, the stroma removed by centrifuging. The saponin solution was added to each fluid from a microburet, and the surface tension measured after each addition. It is apparent, from this experiment and from others of the same nature, that blood possesses the power of nullifying the effects of substances that reduce surface tension. The importance of this power in preventing deleterious changes in surface energy distribution may be an important factor in the bodily economy.

The reaction products of both acid and alkali upon hemoglobin have also been studied by this method. These products markedly reduce surface tension, and it is possible that they play some rôle in acid and alkali hemolysis.

HOW PROGRESS IN SCIENCE IS DEPENDENT UPON TECHNICAL MEASURES AND MANUFACTURERS

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It has been frequently said that the modern developments of science are gradually destroying many of the poetical elements of our daily lives, and in consequence are reducing us to a dead level of prosaic commonplace, in which existence is scarcely worth having. The first part of this rather sweeping assertion is perfectly true, but, the second is absolutely untrue.

Science has certainly destroyed, and is destroying, many of the poetic fancies which made a part of daily life. Perhaps one of the prettiest legends in Natural History is that of the Paper Nautilus, with which so much poetry is associated. All remember Pope's lines, "Learn of the little Nautilus to sail," and many people are quite incredulous when told there is just as much likelihood of seeing a mermaid curl her hair as to see a nautilus under sail. It is, therefore, partially true that science does destroy romance. But, though she destroys, she creates, and she gives infinitely more than she takes away, as shown in the many late discoveries which have transformed the whole system of civilized life.

Let us take one analogy of shattering the legend of the nautilus. Nature produces a marine animal which really does sail, and does not appear to be able to do anything else. I refer to the Velella, a type of jelly-fish, remarkable for having a sort of skeleton, if it may be so called, consisting of two very thin and horny plates giving almost an exact imitation, or perhaps I had better say, precursor, of a raft propelled by a sail. These are often found after being driven in by a rough sea, in quantities, on the shore of Tenby, so well described by Gosse. They are called by the natives "Sea-butterflies" and by sailors "Sally-man," i. e., Sallee-man.

No doubt the first idea of locomotion in water, independently of swimming, was the raft, and the development was from it to the boat. A Kruman's canoe into the *Leviathan,* or a modern iron-clad vessel, is simply a matter of time. We well know the use of a

tree-trunk in the water, how we added a second to prevent turning over from our weight, then spacing them and cross-bar nailing; this to avoid upsetting of the raft. And this still survives in that curious mixture of the raft and canoe, the outrigger boat of the Polynesians, which no gale of wind can upset. It may be torn to pieces by the storm, but nothing can capsize it as long as it holds together. No doubt this construction was based, even then, on the theory of displacement.

Nature's teachings have had their bearings in almost everything we do or make. We know air expands when heated. Liquids, metals, etc., do the same, and we take advantage of this principle in the formation of the thermometer, or "heat-measurer." This expansion by heat is so powerful in iron, that it is utilized in many ways. An example, wheel-making, and the placing of tires. In buildings where iron is used, as in beams and bridges, it is necessary to make allowance at both ends, so as to permit the iron to expand on a hot day and contract on a cool day. Buildings formed of stone and iron were once thought to be safe in the case of fire. Today, they are known to be just the contrary, the stone flying with the heat, and the iron expanding. Here we have learnt to study the values of building stone by the advance of geology, the metallurgical researches of alloys, steel, value of X-rays for the detection of stress, faults which are not visible to the naked eye. When we add that instrument of precision, the miscroscope, we soon learn there is hardly any industry or science branch that can be understood without it. It may seem a long way from the fossil-beds of the Paleontologist to the oil-wells of motor power; from the depths of the ocean to the fish-foods, to the knowledge in hydrographic work by these small organisms, that we are on their best feeding grounds for certain types, that the ocean bed has changed, to their use in buildings. Such is the case, for diatomite is used in nearly every branch, from the making of fireproof brick, chemical filtering, refrigeration, retaining heat, tooth-powders, cleaning, scouring, drying, to making explosives, and giving a peaceful study of the beauties of the Creator's work, under microscopic examination, to the mathematical arrangement of the well-known "Group-slides." From their wonderful structure the testing of object-lenses has required more perfection of glass-making, methods of mounting, more accurate knowledge of the management of the instruments used and their mathematical principles. Optics, lighting, the use of better media with accurate index of refraction

higher than balsam, etc., to the use of our new synthetic resins from the study of coal-tar products.

Notable amongst these are phenolic bodies and aldehydes, of which phenol and formaldehyde are, respectively, the best known, through the work of Bayer, in 1872. Not till 1909 did an American chemist, Baekeland, produce a resin of great value, and superior in quality. Indeed, this is one of the wonders of chemistry, that such a product could be made from such raw materials and become a universal utility. Over a hundred years ago, Sir Robert Peel, the great English statesman and financier, said that the future belonged to the nation which could produce the most coal. A German writer in 1910 said, "The future belongs to the nation which makes the best use of its coal resources." As Professor Goode said in a lecture before the Sigma Delta Epsilon group at the University of Chicago: "This city is in the iron and coal belt, with its water-ways, its rail-centre, its industrial opportunities, its institutions of learning, *it must* become the City of the Future." To this I would add coke, for in its making we get the by-products from which thousands of new products indispensable to present day standards of living are produced.

To whom must we turn? To those who are not only engaged in educational work but also to all manufacturers who are vitally concerned with the question of physics and technical methods as applied to industry. This means they must create departments in which the use of instruments to carry out these experiments have to be designed, also to test for perfection, to see they are metallurgically correct to stand use in shops; by perfect tempering to withstand varying temperatures. An important factor is cost, which in science research must unfortunately be high. For unless the instrument is one for general use, few are made; hence the designing costs are to be considered. Fortunately, we could train, if we would, our youth better in manual arts, to take laboratory positions in technique, and which should be attached to every institution and hospital. One working there sees the need and can often design a simple practical tool that surpasses the manufacturer's because its use is better understood. It frequently happens that instrumental methods are valuable for researches of quite a different character from that for which they were developed, and workers who may be interested in apparatus as distinct from results obtained may never see them or know of their existence.

The field of research is so wide few can keep up with the possibilities of new methods and instruments; also it is difficult to obtain definite information as to construction, capabilities, and limitations. The importance of the knowledge of methods of measurements depend on their accuracy, sensitivity, tempering of metals used, and the student. One may not be mechanically inclined to construct the machine he needs to carry out the work on which to found such an analysis.

An example may illustrate: The Einthoven string galvanometer, with photographic recording, was developed primarily for physiological purposes, in order to investigate the minute differences of potential generated between different parts of the body in synchronism with the action of the heart. During the war it displaced several other methods of recording the small intervals between the times of arrival, at a number of accurately located telephone transmitters, of the air wave produced by the firing of artillery or the bursting of a shell, by which their positions could be determined to a few yards. Later it has been applied to the measurement of several types of transient and periodic phenomena, for which it is frequently more suitable than other types of oscillograph.

Methods of measurement and instruments are becoming of great interest to the biologist and physician, who are making wide use of physical methods in their studies, and are naturally in need of guidance as to the values of such methods, with which they may not be familiar. Here is a point for exhibitors, who can show what the tools can be capable of doing. Watching these demonstrations often suggests new methods that may be of untold value, to both. A manufacturer would rather learn an instrument can be used for several methods, and so aid in selling and reducing costs. Inventions are therefore most desirable if they can be proved usable and valuable to warrant the cost of production. Many of the maker's difficulties in design and construction would be diminished or removed by cooperation and good demonstrations and literature. State-aided research has added to the importance of a work of this nature.

Most problems resolve into physical, or chemical, such as measurements of mass, temperature, density, polarimetry, colorimetry, etc. They require the assistance of engineers, biologists, physicists, chemists and microanalysts, to apply the methods to the problems provided by the living creature. Physiology is a study of

dynamics, in its widest sense, of life, confined within the cell, single or multiple. Microscopic development has grown through the needs of biology, and probably has had the greatest influence in the study. Again, in colloidal solutions, i. e., of the media in which living processes occur. Improvement in dye-reactions, methods, the use of the ultra-microscope and violet light, photographic plates, films, and color-screens. Now research of muscle has become more of a physical and chemical study into causes of muscular activity and its effects.

But the living cell is the means to the end. And whether the instruments, technique, can be made to yield not only form, but chemical and physical constitutional activities, is the problem. The Braggs have shown by direct physical means in large objects, that molecular arrangement can be detected. Whether any application of their methods, or of the microscope, could be made to show the regularity existing in the structure of the living cell, we do not know; if it could, we might be nearer solving one of the most fundamental problems in physiology. Bayliss (Proc. Roy. Soc., 91B, p. 196, 1920) using intense dark-ground illumination, showed that the pseudopodia of *Amoeba,* which are apparently clear, are filled with numerous minute particles in Brownian movement, and that their movement can suddenly be stopped by electric stimulation. To those who have seen the production of the "Canti Film" little more need be said.

The applications of these or other physical methods to microtechnique, e. g., the use of short ultra-violet light and higher magnification, the advance of instantaneous and color photography, or a more accurate study of how far vital or non-vital stains and fixatives produce effects, may yield future results. Also the question of foods and chemical metabolism and modern lighting appliances to the microscope must be noted; for at present the microscope is not able to render the aid the physiologist or biologist requires of it, as it is still imperfect. Some of the most beautiful and successful physiological work was that done by the late Keith Lucas who was almost a wizard in designing, making apparatus for the particular problem he wished to solve. The smallness of the units in use where the changes take place requires finer apparatus, also more speed; hence photography is displacing other methods of recording physiologic changes. By this greater magnification, and making working parts lighter, smaller in size and more simple,

recording becomes easier, and reduction to micrographs can be done for preservation. Various "graph" methods need improvement. Here the optical recording is an advance. If *times could* be required accurately, for example, the interval between the electrocardiogram and pulse, or as in an investigation of the velocity of the pulse wave, an electrical method is very effective.

Here is a field for the electrician, and today we find many instruments of this nature. Electric methods are used in the study of the physico-chemical properties of the body fluids, e. g., hydrogen-ion concentration of blood, and a really effective electrode would be a benefit. The X-ray needs to be studied in its application to the effects of the rays themselves on the living cells, and this might lead to some results upon the physical-chemical organization of the latter.

Perception of sound, color, and other senses opens many problems in research. Helmholtz, who was eminent both in physics and physiology, gave his life to further such research. To Edison, Michaelsen, Compton, Einstein, Roentgen, Eastman, Mees, Curie, Pasteur, Ehrlich, our physiologists, biologists, and chemists and other masters of research, we offer our gratitude for their sacrifice to make the struggle of life more beneficial and give comforts never dreamed of in past days. Progress in science is by the efforts of those who group themselves together, giving all and, oftener than not, receiving little for their devotion, passing on with no thought of sacrifice for their own, but for the world at large.

Perhaps it may not be out of place to mention the value of wire cloth, as filter cloths and centrifugal linings are fast becoming leaders in chemical and other industries. This cloth is, and may be, designed to meet specific purposes. Several patents have been secured on filter cloths; in each case there have been reasons for their designs. One was on a cloth designed to compete with, and overcome the deficiencies found in, other filtering mediums. Under the heading of wire cloth there may be numbered over ten thousand different meshes, sizes, and grades. This industry originated in Scotland, and the first plant in the United States was started at Belleville, N. J., some 100 years ago, by Scotch immigrants. There is still in operation one of the old original hand looms. To give an idea of the possibility of weaving from wire a square mesh, the following comparisons are given: A mesh of 2½ x 2½ inches can be made of as heavy rod as a one-inch

diameter and can be made of as light a wire as 0.177 inch. Between these two limits are listed 14 different sizes of rod and wire. The mesh then gets finer until it reaches 250 meshes to the linear inch, fabricated from a wire 0.0015 in. in diameter. From this one notes the wide range of differences.

For some time about 80 per cent of our wire cloth came from Europe, Germany leading, while France, England and Scotland followed. A large portion of manufacturers were in Alsace-Lorraine, now rated as French. The finest on record for a time was 350 mesh, but in 1914 a firm in Elberfeld, Germany, started to make a 400 mesh, but none was seen here. The finest in the United States is 250 mesh, in the U. S. Bureau of Standards. About 1912, the Edison laboratories produced a piece of 200-mesh cloth 34 inches wide and 100 feet long complete, using Monel metal wire of a diameter of 0.0021 in. It was used to filter wax. Other uses are backings for tank strainers, centrifuges, filters, malt floors, and washers. It is important in the paper industry; and during the war most important in the chemical industry. We find it extensively used in ordnance manufacture; explosives, mills, cement, paper, glue, and pottery manufacture; dyestuffs production, drug houses, colorworks; food production; and last, but not least, ammonia oxidation.

The trade names of wire cloth are many. A few: Metallic filter-cloth, bolting cloth, brass lawn-fly screen, Dutch cloth, Fourdrinier wires or paper machine cloths, washer-wires, centrifugal liners, etc. Care must be taken in knowing this wire cloth before ordering as there are different ways of measuring. And it is well for users to write makers for their catalogues giving details of sizes, openings, etc. The term "mesh" means the number of meshes or openings per linear inch each way, measuring from centre to centre of wire. In the heaviest 4 x 4 mesh the opening measures 0.115 in., whereas in the lightest the opening would measure 0.222 in. So in order to get a ¼-in. space, the size of the wire must be specified along with the size of opening. An example: A wire cloth of 0.083 in. wire with an opening of 0.250 in. would be a 3 x 3 mesh. A difference of 0.001 in. in the diameter of wire would make a considerable difference in the finished product, both from a manufacturing and working standpoint. Hence, accuracy in manufacturing is a necessity, and the Bureau of Standards the proof.

The value of Monel cloth is shown in replacing old-type fabrics, as jute, hemp, cotton, it being more easily cleaned, stronger, and impervious to weak acids, alkali-proof solutions. Monel has stood solutions with from 7 to 10 per cent sulfuric acid. Only one case of failure was in a press using cast-iron plates and Monel metal filter leaves for the precipitation of potassium permanganate. In this case the filter leaves rapidly decomposed because of the electrolytic action set up. A most interesting microscopic-ground glass screen view can be seen of the filtering of various micro-organisms through the cloth. This type of cloth is being extensively used as lining for centrifugals, is strong, easily cleaned, with a weight of about 9 ounces to the square foot. Its weaving principle uses 500 wires in one inch of space, which are spirally overlapped. I believe its alloy is composed of Ni 67.5 parts; Cu 30.5; Al 0.5; Fe 1.5.

And so it goes. I have only attempted to touch on a few of many important questions which the title of this paper has raised. For instance, there are many romantic sidelights to every industry or profession and many are complex to ours.

The optical needs but the pen of a chronicler to make a fascinating narrative. One of these is the use and history of corundum, which is, next to the diamond, the hardest natural substance. It is used as an abrasive for grinding glass, rocks, etc. South Africa yields the finest so far known, in trade called "Premium ore" and costing about one English pound a ton more. One dealer tells his deposits are 12 miles from the railroad in a direct line, but he is forced to go 60 miles on account of the deep ravines. Briefly, the preparation is to put the ore through large crushers to about 1½-inch size or finer, then through small crushers, to give ½ inch, ¼ inch or finer. Now through sieves, rolls and screens to sizes needed, these being controlled by hummer-screens, in the rolls. From the hummer into wet mulls, agitated, and washed about 2½ hours. In the mull it is pounded to separate the grains, to make them the proper shape and texture as a commercial abrasive. From the mull, shovelled to draining boards, to driers, to storage, then to the grading room. Here screening is done to get the grades for commerce. A firm that manufactures optical goods, microscopes, physical apparatus must further break down the corundum, wash it, purify, and grade most carefully if used for lenses. Here the operations are *most* precise and carefully controlled. When I mention that over 30 grades are selected, with

the difference in size between some of the smaller being about .003 mm., you can understand how the progress of science depends upon technical methods and manufacturers as well as the professional workers.

Those who crave fame and fortune we hope will find both, if they will only produce the solution to certain important problems, which are worth everything to human progress. The fields of biochemistry, physiology, optics, medicine, sanitation are all open to those who can solve the perplexing question vital to the world at large. The discoverer should be repaid with more than thanks and a few medals, for he needs to preserve his body and maintain health, also his family. Let the future equal if it cannot surpass the results of Lister, Pasteur, Trudeau, Manson, Gorgas, Wood, Curie, Steinmetz, Edison, and many others.

A NEW MECHANICAL DEVICE FOR INTESTINAL SURGERY

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Bacon Clinic, Macomb.

Previous to the last quarter of the nineteenth century, operating for any purpose within the abdominal cavity was considered absolutely unjustifiable. Although earlier cases were reported as having recovered from such an operation, they were so rare as to have become historical. In the last quarter of the century the great Pasteur revealed to scientists the existence of germs and demonstrated their growth. Immediately after the publication of this epoch-making discovery, Sir Joseph Lister proclaimed to the world that now we had the secret of blood poisoning and infectious diseases. He began teaching the use of chemicals to destroy germs, such as carbolic acid, etc., for dressing wounds, cleaning instruments, sponges, dressing for wounds, hands of the operators and assistant nurses, etc., with astounding results. Listerism, or anti-septics, led up to the present ideal method of asepsis, one of the greatest scientific gifts to mankind. The laboratories came to the assistance of the surgeons. Antisepsis improved the condition of wounds, and surgeons began operating within the abdomen, but the mortality was great. The surgeons were not satisfied with their work. As a result the medical and surgical literature from 1880 to 1900 was enriched with original articles, especially dealing with intestinal survey. A new field of surgery was to be developed, new methods of sewing, new materials, new needles—nothing was satisfactory. Then a universal effort was made to develop new mechanical devices to take the place of sutures, and innumerable devices were tried and discarded in time. Meantime the method of suturing was constantly improving, and today a method rarely noticed in surgical literature has practically superseded all other methods and mechanical devices.

One of the greatest surgeons of the world, in a recent classical work on surgery, states that all mechanical devices for intestinal surgery are nuisances. But it is recorded that the same was said of the first steam engine. The facts are, that the mortality in

intestinal surgery is great, and that the present method of suturing is not satisfactory. Proof of this is evidenced by articles now appearing from noted research workers in the leading surgical journals, describing new methods of sewing and criticising former methods, exposing their defects and trying to achieve perfect asepsis, an almost impossible thing to accomplish on account of the unlimited number and variety of germs inhabiting the intestinal tract.

Each individual stitch must work perfectly or the result will be disaster. The greater their number, naturally, the greater the danger.

My new mechanical device requires no suturing. It involves the use of a rubber ring which obviates any possibility of leakage.

The intestinal clasp-ring is a mechanical device for safe and rapid end-to-end anastomosis. By means of this instrument the ends of the intestine are held in secure approximation, which prevents leakage and insures a complete union before the instrument becomes detached and is passed down the bowel.

The apparatus consists of a light metal tubular clasp, an inner cylinder and two thimble-like rings of the same material, and a rubber ring.

The procedure is as follows: A purse-string suture is placed in each end of the intestine to be approximated. The clasp part of the instrument is placed within one end and the ring part (previously tied with catgut to the rim of the cylinder) in the other end of the intestine, and both ends then tied firmly around the cylinder, which has been pushed part way into the tube of the clasp, the whole being held firmly by special forceps grasping the cylinder just between the two ends of gut. Grasping the clasp through the intestinal wall with the thumb and finger of one hand and the rings with those of the other, the two parts of the instrument are pushed together until they click into place. Then by pushing the outer metal ring forward, the rubber ring slides off the inner metal ring on the clasp, where it anchors all the layers of both ends of the gut, serosa to serosa.

The catgut holding the two parts of the instrument together temporarily is soon digested, permitting the two parts to pass along the intestine separately.

This instrument is an improvement upon, and the idea an outgrowth of, my former instrument, the intestinal dumb-bell, advocated for the same purpose and published in the American Medi-

cal Journal, January 6, 1906, together with the end-results of operations performed upon animals up to that time. The dumb-bell operation was justly criticized because an extra incision had to be made in the intestine, so the operation was not performed upon the human subject. Yet all the animals recovered and post-mortem inspections made after intervals of a few days to eight months showed perfect results, no contraction, and a minimum of scar tissue at the site of the operation.

The same principle that governed the previous operation governs the new procedure; that is, all the connective tissue of both ends of the gut is taken in one ligature. Any possible leakage or infection at the line of the union is thus prevented, and the connective tissue is held in place so that the serosa and muscularis, both of which quickly atrophy under pressure, can retract from the ring and unite end-to-end before the connective tissue is severed by tissue atrophy. This usually occurs in about six days.

The advantages of this method of intestinal anastomosis are: (1) the simplicity of the operation, (2) the absolute safeguard against leakage, (3) the short time required for operation, (4) the dispensing with the necessity of reinforcing sutures, (5) the short time which the instrument remains at the site of operation (due to the uniform necrosis of all connective tissue within 6 days), and (6) the minimum amount of scar tissue remaining.

THE ROSENWALD INDUSTRIAL MUSEUM

MARION F. WILLIAMS
Rosenwald Industrial Museum, Chicago.

Founded by Mr. Julius Rosenwald's gift of $3,000,000 for equipment, the Rosenwald Industrial Museum (as it is provisionally called) will eventually occupy the old Fine Arts building in Jackson Park on Lake Michigan, the building to be suitably reconstructed in steel, cement, and stone. For this purpose, the South Park Commissioners of Chicago have issued bonds to the value of $5,000,000.

Already unsolicited donations of exhibits amount to over half a million dollars, and undoubtedly the museum collections will eventually reach a total of at least $30,000,000, thanks to the interest and generosity of the scientific and industrial world. In Germany, when the famous Deutsches Museum of Munich was founded, about 1903, many cities, rulers from the Emperor down, and every important manufacturing corporation, contributed either machines or money to insure its success.

Visual education will be presented here in a new form. Whereas the scientific and industrial museums of Europe have been satisfied to show the historical sequence of technical principles and processes, the Rosenwald Industrial Museum—and this is a most significant forward step—will interpret the cultural effects of science and industry.

This will be done by dramatization—using three-dimensional models (operative by crank, push button, or lever), paintings, charts, motion pictures, machines sectioned to show their internal mechanisms, and dioramas, acting as miniature stages on which the model of an entire industrial plant can be shown against a painted background. By this means, one sees the plant in its proper setting, while a motion picture reveals scenes of activity and depicts the actual processes of the work being carried on within the factory itself.

Interrelationships will be brought out, so that one may grasp the social and economic problems raised by the various inventions.

It is possible to link machinery and instruments to human progress in a striking way, if for example we consider the microscope and the telescope as extensions of the human eye. Think, too, of a huge bucket, steam-actuated, as the extension of the five fingers of the human hand (which grasps a few ounces as compared to the tons of earth so displaced), and the comparison can easily be carried further.

Power—when unleashed—is a demon of destruction. When controled, it becomes man's servant. How has man slowly but steadily harnessed energy and made it his slave? How much energy is generated by the human body in health and in disease? The Museum will answer the question: "What do inventions mean in our lives?" Have they in reality increased our social and economic problems while apparently lessening our labor?

Without machinery, could the civilized world of today be fed? Suppose there were no chemical fertilizers, mechanical plows, or agricultural machinery; no transportation by steamship and railroad? Suppose the surplus of one year's harvest could not be preserved by packing, canning, and refrigeration? What of the deficiency of a lean year?

This opens long vistas of thought. In our machine age, industrial problems of housing and sanitation have arisen, which science must solve. We turn to the bacteriologist and the sanitary engineer to drive out typhoid and tuberculosis and to provide suitable lighting, heating, ventilation, and sanitary systems.

Again, to what extent is the invention of the elevator responsible for Chicago's skyscrapers and apartment buildings? Is it not socially related to vehicles of transportation, such as the bus, the elevated, the street car, the suburban train?

Then, too, what economic pressure has determined an invention such as the steam engine? In England, when the forests were exhausted, coal became a necessity. Horse-pumps proved inadequate to drain the mines, but it was at least a century before the steam pump was evolved. Progressing from the steam pump, James Watt's steam engine became a possibility. Could he have evolved it without the former invention? Later, men built upon these primitive efforts, until now we have the super-locomotive and the modern silent steam turbine. Today the inventor is rapidly becoming anonymous, and technical progress is systematic and predictable. Organized research, sponsored by business men and carried on in laboratory groups, may one day usher in an era when

some of our foods may be commercially synthesized out of familiar gases.

For the chemist has invaded fields seemingly other than his own. He assists the metallurgist, for example, and to him is due the long list of products now obtainable from coal tar. Synthesized drugs, perfumes, even explosives, mark some of his achievements.

Chemical and physical experiments, too, may be performed by the public. For example, imagine the reproduction of a corner of Michael Faraday's famous laboratory, and see yourself performing some of the very experiments by which the great experimenter reached conclusions of such significance to modern electrical engineering.

The Rosenwald Industrial Museum will have a hall devoted to "Concepts of the Day." Here, proposals that are under consideration, projects that are worthy of study, may be shown temporarily (such as the English Channel Tunnel scheme, for example). What seasick traveler would not welcome a train trip from England to France instead of the present uncomfortable and much-dreaded channel crossing?

Television, too, would be represented by a model which would show its underlying principle and indicate the possibility of producing in one city a play that is seen and heard in other great centers.

Frequently time and space must be telescoped. Hence, the development of the street from seventeenth century London to our day may be shown, in perhaps 50 feet, by a street divided into periods of time. Here one progresses from the mud, filth, and flickering torches of Elizabeth's reign, by various stages, to brilliantly lighted Michigan Avenue, sectioned to show its asphalt, its water and sewer mains and underground conduits.

Since space forbids the inclusion of every important railway vehicle of the past century, a car will be divided into periods. The first compartment will be mechanically shaken to reproduce the discomforts suffered by our grandfathers. A glance out of the window will show the landscape of that time by means of an illuminated painting, traveling ceaselessly on rollers. The last compartment will be a modern Pullman sleeper, its motion scarcely perceptible, while from its windows arises a painted vista of the skyscrapers of Chicago.

In Germany, museum visitors walk through ten miles of exhibits and do not seem to quail before a curator's lecture of one hour and three-quarters on the objects in his division alone.

In Chicago we shall not tax the inquiring mind so heavily, but we hope that the thrills of descending to a real coal mine, or seeing for the first time the bones of one's own fingers portrayed upon a fluorescent screen by means of the X-ray, of watching an engine turn a crank-shaft, or facing electricity flashing and crackling, may so engross a boyish mind that dinnertime will be forgotten.

While science can not crowd crime off the front page of the World's Greatest Newspaper, it is hoped that the Rosenwald Industrial Museum may help many an earnest lad to find his life's vocation, and prove an inspiration and encouragement to students, engineers, and inventors, by showing them something of the trend of the future, as well as retelling the story of the past.

PAPERS IN PSYCHOLOGY AND EDUCATION

EXTRACT FROM THE REPORT OF THE CHAIRMAN

In the High School Science Section, following the address by Dr. Hopkins, the Illinois Association of Chemistry Teachers presented prizes for the best exhibits of chemical products made by students. Bloomington High School took first prize and Rockford High School second prize.

At the business meeting of the Junior Academy of Science, under the supervision of ten visiting high school teachers, the following officers were chosen for 1929-1930:

President—Robert Prindle, Rockford High School.
Vice-President—Drexel Mey, Decatur High School.
Secretary—Iola Berndt, West Chicago High School.
Treasurer—Hugh Irwin, Bloomington High School.
Manager—Gordon Cedarleaf, Rockford High School.
Faculty Adviser—H. W. Garnett, Bloomington High School.

S. ALETA MCEVOY, *Chairman.*

OPPORTUNITIES IN SCIENCE*

B. S. HOPKINS

University of Illinois, Urbana.

"All the important discoveries in science have been made and it is impossible for the new generation to make any material addition to the sum of human knowledge." Such a sentiment as this is frequently met, especially among those who are just beginning the study of science. As one looks back over the centuries of human history, he realizes that the civilization of today has the advantage of the accumulated knowledge of the wise men since the beginning of time. He is led to believe that in all this panorama of human progress, certainly there can remain no fundamental discovery for future generations to make. He feels that he has no opportunity to add to human comfort, safety, health or happiness because he is in competition with the accumulated wisdom of all sages of history.

Have all the worth while discoveries of science been made? It is perfectly natural for any age in the world's history to consider itself a little better than anything which has preceded it. But do we have any basis for assuming that our generation is wiser or more proficient than those which are yet to come? The comforts and conveniences which are new to us will become the commonplace essentials of the next generation while new contrivances will add materially to the efficiency and comfort of human existence. Greater discoveries remain for future workers than have yet been revealed. These discoveries of the future will doubtless be of a different type from those of the past, but I am firmly convinced that they will add to human society factors as vital and as useful as any of the basic discoveries of the previous generations.

In attempting to prove this viewpoint it is necessary to consider the opportunities which have been enjoyed by the younger generation of scientists of previous periods. We can predict the future only by a careful study of the past. Young people of other days have been confronted by problems similar to yours, and it is an inspiration for us to see how these problems have been solved. Surely, with all the advantages of our generation manifest in such

* Address to the state meeting of the High School Science Clubs in conjunction with the State Academy of Science, Macomb, Illinois, May 3, 1929.

a multitude of ways, there must be some work left for you to accomplish. Let us see how the problems of other days have been solved.

There are few things more inspiring to younger students of science than the history of the aluminum industry. Just recall that aluminum is the most abundant metal of the earth's crust. There is more aluminum within the reach of man than any other metal. Yet the amount of aluminum used today is insignificant compared with the amount of iron that is used. For many years it was not available at all, and at present it is available only at a high price. Why was it so long in arriving? Because it is never found in the uncombined form, and is generally found in compounds which are very stable. It has been very hard to get it out of these compounds. Some of the most skillful scientists of both Europe and America had worked long and faithfully at the task, but their results were not satisfactory. One day an American boy, Charles Hall, just graduating from Oberlin College, found the secret which made possible the aluminum industry. He found that the aluminum ore, bauxite, dissolved readily in molten cryolite and that upon electrolysis this solution gave the metal aluminum. All of this metal which is used today is prepared by relatively simple modifications of the Hall process.

Two tables will show how the aluminum industry has grown. Table I shows how the price of this metal has fallen as the methods of production were improved, while Table II shows the rapid increase in the use of this interesting metal. It is worthy of note that in the early days, aluminum was a precious metal, although its compounds were "as common as dirt" and "every clay bank along the road side is a potential mine of aluminum." In those early days it was a curiosity available only in very small quantities. It was produced by the use of sodium, itself an expensive metal. The drop in price in 1856-57 was due to an improved method of producing sodium. The fact that for a quarter of century the price of aluminum did not change, indicates that from 1862 to 1886 no progress had been made in the solution of this problem. Hall's discovery in 1886 brought a great increase in production and a corresponding decrease in cost. This great industry stands today as a monument to the work of an American youth, and as an inspiration to young scientific workers everywhere.

But, you may object, this work has been done and there is nothing left for us to do. Let me tell you that the aluminum industry is yet in its infancy and there remain many problems worthy of your best efforts. Aluminum is an essential component of light alloys, and this is a field which is even now attracting very wide attention. Great developments along this line are to be expected in the near future. In addition to its alloys we need to know more about the metal aluminum and its capacity for serving various uses. We know little now about welding, soldering, or patching aluminum, and these problems must be solved. It is safe to say that we have scarcely begun to know aluminum and that great studies in this line are to be expected.

TABLE I.

COST OF ALUMINUM PER POUND.

1855 in England	$275.00
1855 in U. S.	90.00
1856	27.00
1857	22.50
1862	12.00
1886	12.00
1913 (November)	0.19–0.19½
1917 (January)	0.63–0.65
1921 (January)	0.27
1929 (April)	0.24–0.26

TABLE II.

PRODUCTION OF ALUMINUM IN AMERICA.

1883	83 pounds	
1885	283 pounds*	
1895	920,000 pounds†	
1900	7,150,000 pounds	
1905	11,347,000 pounds	
1910	47,754,000 pounds	
1915	99,000,000 pounds	
1918 (War Period)	225,000,000 pounds	
1926	304,000,000 pounds	or 152,000 tons

A few years ago throughout the cotton growing states there existed a difficult problem in the disposal of the seeds which were separated from the salable cotton fibre. These seeds accumulated in such tremendous quantities that they became a nuisance and their removal involved large investments of both time and money. Now this situation has been forgotten, for cotton seeds form a valuable part of the crop. From the short cotton fibers which cling to the seeds are produced batting, stuffing of various kinds,

* New method of getting sodium perfected.
† Hall's process came into practice.

and cellulose from which rayon, writing paper, explosives, and celluloid are manufactured. From the hulls we get stock food, fertilizer, and fiber; from the meal we get cattle food, flour, and dyestuff material; from the oil we get a great variety of products including cooking oils, lard substitutes, butter substitutes, preserving oils, soap, glycerine, dye-stuffs, and paints. The cotton seed industry is now the second largest industry of the south, involving hundreds of millions of dollars annually. There are many opportunities for new developments along many lines in these industries which are very new and which contribute vitally to our modern civilization.

Not many years ago the only method of manufacturing coke was in the so-called beehive coke ovens. People did not like to live in the vicinity of these ovens on account of the smell and smoke which were always present. Coke is now made in the by-product coke oven, and the smoke is made into many of the most useful things we know. The coal tar tree represents the products obtained from this waste. The most brilliant dyes, beautiful in the extreme, are a product of this waste material. We have much better dyes than were known even a few years ago. In addition, out of this coal tar nuisance we get valuable medicines, antiseptics, disinfectants, perfumes, fertilizers, explosives, photographic materials, preservatives for both food and wood, road materials, roofing materials, and almost a countless number of things taken out of the material which was such a nuisance a few years ago. The chemist has a pardonable pride in the accomplishments shown in the coal tar industries. Yet, great as these savings are, much more remains to be accomplished. A total of approximately 40,000,000 tons of coal is now consumed annually in the by-product coke ovens, while several million tons are still used in the old beehive ovens, which belche forth such unpleasant smoke, and 200,000,000 tons are used annually as fuel. Notice what a small percentage of the total coal consumption in this country permits the utilization of those by-products which are so useful and valuable. Will the time come when we will heat our homes by some better method than by burning this smoky coal? I believe it will, and this is a problem which must be solved by the coming generation. Somebody will have to do the work that has not yet been done. You think the scientific problems involved in the coal and coke industries have been exhausted? They have scarcely been touched. The opportunities in that connection are limitless.

One of the greatest problems which confront the scientific workers of our generation is the elimination of wastes. Much has been accomplished along this line, but much more is waiting for careful painstaking study. One of the problems which are just now beginning to receive attention is the waste on the farm, especially such materials as cornstalks and straw. The enormous need of farm relief along such lines is very much in evidence as one rides across country in this fertile corn belt at this season of the year. Not only are cornstalks and straw quite useless, but they are a nuisance, and their removal is expensive and time-consuming. These products of plant growth contain cellulose, and if we once learn how to extract cellulose at low cost, great industrial developments may be expected; for from cellulose is prepared paper, gun-cotton, artificial silk, celluloid, photographic films, and even stock feeds, sugars, alcohol, and many other important materials. Already a start is being made in our own state in the utilization of these farm wastes, for at Danville there is now being made a high-grade paper pulp from such waste materials. The cost is now high, but as forests are removed, the cost of wood pulp must of necessity increase; so it is evident that here is an opportunity from which much may be expected.

If we turn to the realm of medicine we find that there are many, many opportunities for the young chemist. Many people are dying daily from diseases for which we have no remedy. We do have a form of treatment for pneumonia, but no remedy. The common cold involves a greater financial loss than some of the more virulent diseases, and we have absolutely no cure for it. We might also mention pleurisy, anemia, goiter, and leprosy. There are thousands of lepers living under the American flag today, mostly in our island possessions but with a surprisingly large number in various localities of the United States proper. We have ways of controlling the disease which were not known in Biblical times, but we have no cure for it. We have no cure for syphilis, diabetes, scarlet fever, tetanus, sleeping sickness, and many other diseases. They have been somewhat successfully handled, but there are no specific remedies. We need new germicides, antiseptics, etc. We need to learn much concerning the important glands and their hormones, and the effect of ultra-violet light, with its influence upon health. Surely the field and medicine is teeming with opportunities. I believe that there are more opportunities for

you who are now entering the field of science than have been offered at any previous period of the world's history.

The illustrations I have selected are those which appeal mainly to the chemist, because that is the branch of science with which I am most familiar. It is certain that other branches of science offer opportunities which are equally attractive, and many important discoveries must be expected in those lines also. Perhaps these developments of the future may not be fundamental in their nature, but they will contribute none the less to the happiness of mankind if they are concerned with the improvements and adaptation of principles already recognized.

Have respect for the history of science, revere the accomplishments of the science of today, but do not take the attitude of the pessimist and assume that we know it all. Be an optimist and believe that your opportunities are as good or better than have ever been offered to any generation in the history of the world. Study science as a living, growing, expanding unit whose usefulness depends upon the skill, devotion, and untiring effort of those who select science as their best means of adding to the world's happiness.

I cannot stop without preaching a little sermon. I wish to compliment you very definitely on your initiation ceremony. I was pleased beyond expression to see a scientific club introduce its initiation ceremonies with silent prayer. Many people believe there is a conflict between science and religion, but there is no such conflict. Let me give you my definition of science and religion. Religion is God's truth as it is revealed to man. Science, as I see it, is Nature's truth as man understands it. There may be conflict between our interpretation of God's truth and our interpretation of Nature's truth as we know it in the study of science, but truth cannot quarrel with itself.

Young people beginning the study of science are living in a wonderful age. You hear a great deal about "joy rides" and "whoopee" parties of all sorts, and you get the idea that that is the life. Don't you think it. Remember, civilization is many centuries old and is built on conventions which have come down to us from generation to generation. Do not think you can overthrow those conventions with impunity. The essential thing for a scientist is to keep his mind clear. One cannot engage in these "whoopee" parties and have a clear mind. Alcohol has great value, but I believe Providence never intended it for an internal use,

except possibly as a medicine under the skillful advice of a reputable physician. Keep your mind clear. These problems I have outlined to you will require intense thinking and hard work. Do not think you can sit on a park bench and dream your way to prominence by making a discovery. Discoveries are made by hard work. It takes a clear mind back of hard work to bring success. Do not believe that the wild stories you read in the papers are the common experience of life, for they are the unusual. If you are going to be successful as scientists, keep your wind clear and your conduct beyond reproach.

ON THE EFFECT OF SIMULTANEOUS TACTUAL-VISUAL STIMULATION IN RELATION TO THE INTERPRETATION OF SPEECH*

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[An earlier published reference by the author to the research and its results as described below has led the distinguished Professor David Katz, of Rostock, Germany, to direct an independent investigation of the same nature as that discussed in the following pages. Under date of November 24, 1929, he wrote to the author saying that one of his pupils, "Herr Thiel, has found that in the instruction of the deaf a very much better result is obtained if the *feel* of the spoken word is communicated to the lip-reader by the use of special vibrators." This is confirmation of the conclusions that follow.—R. H. G.]

Psychologists and many other scientific folk are aware, at least in a general way, that this Laboratory has, for several years, been engaged in experiments with the sense of touch. Through the organs of this sense, observers are detecting and distinguishing various rates, intensities and complexes of vibration in a solid body. In a larger way, the first question of the Laboratory is: How far can one go toward learning to identify tones, vocal elements, words and sentences by means alone of the tactual impressions that are occasioned by their vibrational characters in our laboratory situation? The second question is: Can the tactual experience of speech be profitably employed to supplement the eye of the deaf, e. g., and to aid them in interpreting spoken language?

The experiments from which we obtained the data reported here were made on December 8th, 9th, 14th, 16th and 17th, 1925; on January 14th, 17th and 26th, 1926; on May 6th and 17th, 1926; on January 2nd, 17th and 18th, 1928; and on December 9th, 1928.

Prior to these experiments, the subjects had participated in laboratory experiments with tactual stimuli during an aggregate number of hours that varied with the individuals. The median is 78.5 hours.

INSTRUMENTATION

The instrumentation employed in this enterprise is designed, of course, to transmit sound. A telephone-like apparatus is used to carry stimuli from the source of energy (e. g., a speaker's vocal

* The research reported here was done under the auspices of the Carnegie Institution of Washington, in the Vibro-Tactile Laboratory.

apparatus) to a receiver that the subject or observer holds in his fingers. This receiver vibrates in unison with the speaker's voice and the subject feels the voice. At the other end of the system is a microphone at the mouth of the speaker or against his cheek or larynx. Between the michophone and the receiver are a six volt A battery, a 120 volt B battery and three tube amplifier. We use six or eight receivers simultaneously. Each of them (in the form of apparatus we have used exclusively in the course of experiments reported here) is a device operated by a single magnet. It has a diaphragm whose natural frequency is 800 d. v.

The entire system we call the "Teletactor." It has been designed and contributed for our use by Bell Telephone Laboratories of New York City.

TACTUAL STIMULATION AS AN AID TO INTERPRETATION

In this paper, we have assumed, in particular, the task of answering the second question above: does the feel of speech in the fingers, simultaneous with the vision of speech as the lip-reader sees it upon a speaker's face, facilitate one's interpretation. Certain data that have been accumulated in this laboratory, even without further to-do, indirectly support an affirmative hypothesis.

INDIRECT DATA

Data obtained both before and since our experiments on dual tactual-visual stimulation were made, throw a good deal of light upon the question re the discriminations that the sense of touch may be expected to make toward the interpretation of isolated words and sentences. They have already been published, in part at least, and are mentioned, therefore, but briefly here.

1. Vibrational frequencies, at least as high as 2600 d. v. a second, can be detected by the tactile organs.

2. After appropriate training, subjects are able to recognize at least ten vowel and diphthongal elements by their tactual qualities with a good degree of accuracy.

3. Likewise, they detect and distinguish at least ten consonantal and semi-vowel elements.

4. They are able to identify at least 120 sentences by their patterns as felt. This has been accomplished to from 60% to 100% of accuracy in 36 Laboratory sessions of 45 minutes each. (*Pattern* is a term that means a complex of at least accent, emphasis, rhythm, variations of pitch and tempo or speed.)

5. An analysis of 10,140 judgments indicates that one may be expected to detect and locate accent by touch alone in bi-syllabic compounds in over 90% of instances. The stimuli, in this connection, were constructed from thirteen vowel qualities combined with *l* and *s* to make as many nonsense syllables. Each syllable was combined with every other to make bi-syllabic nonsense compounds. These compounds were the stimuli and they were accented now on one syllable and now on the other in unknown order. The subject had to report on whether accent was upon the first or the second syllable.

6. Experiments with 103 unselected groups of homophenes, aggregating 307 words (these are words that look alike on the face of a speaker, and that cannot be distinguished by the lip-reader when they stand alone), show conclusively that our subjects are able to discriminate by touch among the members of all these groups but eight, and to make their discriminations with an accuracy ranging from *fair* to *perfect*. This means that touch contributes data for judgment, in this situation at least, that vision cannot furnish. An analysis of data indicates that the criteria are most probably, in many cases, the feel of final consonants; in others, initial consonants; in others, vowels. In other cases, all these qualities combined contribute a quotum that makes for recognition.

7. A deaf lip-reader, rated as "fair," locates accent by lip-reading little better than by chance, notwithstanding that she has been interpreting speech by this means for twenty years. She has been training in the Vibro-Tactile Laboratory, to the present date (December, 1928), no more than fifteen hours and she locates accent by means of the teletactor, when the speaker's face is hidden, in upwards of 80% of instances. She makes such a record as this even when the pronouncer of the words is one who knows nothing of the purpose of the experiment, and who cannot, therefore, be suspected of unconsciously "throwing" the result in the direction of his preconceived notion. The pronouncer is blindfolded so that he cannot, in either the lip-reading or the touch-reading series, see the subject's face when she is about to make a verbal report. It is impossible for him to guide her by an involuntary sign when he sees her about to make a right or a wrong report. Moreover, the pronouncer does not even know when the subject is attempting to read his face and is out of contact with the teletactor, and when she is feeling the pronunciation of suc-

cessive stimuli, but is prevented, by means of a screen from seeing his face.

In fact, the pronouncer knows only that he is to say "loosloos" or "dubdub" repeatedly, accenting now the first syllable and now the second, according as the director of the experiment (behind the subject and out of her sight) may indicate.

Success at locating accent by touch is a reminder of Dr. Knudsen's saying that the tactual organs can discriminate intensities of vibration as nicely as the ear.[1]

Further experiments are in progress to compare the vision of a speaking face (lip-reading) with the feel of speech as means of learning to recognize sentences by their patterns as wholes; to compare hearing with feeling in the same relation; to compare vision with feeling for detecting and locating each element of pattern aside from accent.

8. The use of the teletactor alone is superior to lip-reading alone as means of becoming acquainted with the number of syllables being spoken. This comparative study has been made in relation only to deaf cases and the reactions to each one have proved the point. Eighty sentences have been employed for the purpose. They were all outside the lists that were requisitioned in relation to other experiments that are under discussion in this paper. The figures in this connection are quoted below:

Subject	Rank as Lip-Reader	Dectection via Lip-R.	Detection via Teletactor
1	Mediocre	24%	40.7%
2	Mediocre	25%	46%
3	Good	35%	60%

DIRECT EVIDENCE

The foregoing paragraphs 5, 6, 7, and 8 contain indirect evidence for the hypothesis that dual (tactual and visual) stimulation from spoken language may be expected to guarantee more successful interpretation of speech than visual stimulation alone (straight lip-reading). Exclusive of these data, the material referred to in paragraphs 1 to 5, inclusive, has been collected for the purpose of discovering what are some of the things that tactile organs can do in the way of receiving forms of spoken lauguage, irrespective of the means by which they can be best received.

[1] For more details of data summarized above see:
Jour. Frank. Inst. Vol. 204, No. 3, Sept., 1927, pp. 329-358.
Arch. of Otolaryngology, Vol. 4, Sept., 1926, pp. 228-239.
Jour. Abn. Psy. and Soc. Psy. Vol. XXII, No. 1, Apr.-June, 1927, pp. 33-39.
Jour. of Gen. Psych. Vol. II, Nos. 2 and 3, 1929, pp. 212-228.
Also: Knudson: "Hearing" with the Sense of Touch.
Jour. Gen. Psy., Vol. I, No. 2, Apr. 1928, pp. 320-352.

What is the direct evidence? Deaf subjects in our Laboratory are enabled to see the face of a speaker and, simultaneously, through the Teletactor system, to feel his words in their finger tips. Do they interpret speech in this dual stimulation situation any better than they can as unaided lip-readers? Briefly, the answer is affirmative, as the indirect evidence suggests it may be. This conclusion is based upon the Laboratory's experience, as has already been stated, with 22 deaf subjects. The median time they had spent in the Laboratory at work, prior to participation in the tests on which this paper is based, was 78.5 hours. Their Laboratory exercises were directed toward training them *to be attentive to tactual stimuli* from the human voice that is made to produce vibration in the diaphragm of the Teletactor system; to distinguish and memorize vowel qualities by their feel; to distinguish and memorize the patterns of English sentences. Their training was about equally divided among these types of exercises.

In all, a total of 124 records were obtained from the 22 subjects. Eighty records were from six observers; the remaining 44 from sixteen observers. Of the 124 records, 108 were confirmatory of the hypothesis: i. e., they indicate a more successful interpretation of speech under conditions of dual (tactual-visual) stimulation than in the straight lip-reading situation.

SUBJECTS

The chronological age of observers in these experiments ranges from six to thirty-five years; median, 23 years. In scholastic status, 17 range from the very beginning of elementary school study to the senior year in college—equivalent, approximately, to the sophomore year in a standard college. One of the remaining five subjects was an instructor in a college for the deaf. Three others had graduated from a school or college for the deaf several years prior to the first of these experiments. The remaining one, six years old, had never been in school.

Their residuum of hearing ranged all the way from 0-0 (0 in each ear) to 60%-70%. The median residuum of hearing in the more defective of our 22 pairs of ears is between 10 and 20%; of the less defective, between 25% and 30%. No one of these could get any help from an acousticon. Eleven are described as congenitally deaf. Of the remainder, all but two are reported as having been deafened in early childhood. These two attended schools for hearing children until they were in their early teens. It is, of

course, impossible now to say whether they were able to hear speech in the course of their last years in the standard school.

Owing to lack of means for making a satisfactory measure of accuracy in lip-reading, we are able to do no more than rank these cases themselves from *no lip-reading ability* to *superior ability.* There is one case at the lower extreme and two at the upper. One of the *superior* ones, for several years, held a situation among hearing co-workers in one of the Government offices in Washington. We think she is entitled to be described as *the* superior of the whole group in this one respect. At the other extreme was a six-year-old case who had no school history. The other cases should all be ranked from *very poor* to *good* lip-readers. Going among them, day after day, one would doubtless get the impression that the median ability of the group is *mediocre,* although their school records indicate a higher rating.

STIMULI

The stimuli that were selected for use in these tests are of two sorts: *words isolated from sentence structures,* and *sentences.* Of the isolated words, there were 200. It is important to observe that they were all monosyllables. Of sentences, there were 116. They contain 1,026 words; 20 trisyllabic; 81 bisyllabic *and 925* (over 90%) monosyllabic words. Furthermore, 89 sentences contained 10 syllables each; six contained 11; 19 contained 9 syllables each; one, 12 and one, 8 syllables. It is important, as we shall see later, to observe these facts.

Both isolated words and sentences were selected from a well known manual for lip-readers, with a view to having all sorts and degrees of lip-readers' problems represented in our lists.

METHOD

The method, in general, consisted in presenting isolated spoken words, visually, in a series and obtaining the subjects' interpretation. (Straight-lip-reading.) The same spoken words were presented, in a distinct series, tactually and visually, *simultaneously.*. (Lip-touch-reading.)

In more detail: from the list of 200 monosyllabic isolated words, the experimenter ordinarily selected 100, (for one test only 50). These were taken from all parts of the total list. For another test, the remaining 100 were taken. A short series of ten words were given for straight lip-reading, followed by a short series of ten for lip-touch-reading, and so on until words in the

list had been given for both dual (visual-tactual) stimulation and single visual stimulation. Never were *identical* short lists of ten given in immediate succession. That is if *a, b, c, d,* etc. are in a given short list for straight lip-reading, the immediately following short list for lip-touch-reading might contain *a, x, c, y,* etc. But, as has already been stated, every member of the total list was ultimately given in both ways.

In like manner, selections were made from the 116 sentences that have already been referred to. In a given test, 58, 30, 28, or 10 sentence stimuli were presented. These groups contained an aggregate of 507 to 529, 266 to 277, 241 to 252, and 114 words, respectively. The modus operandi was altogether the same, whether words or sentences were being employed as stimuli.

In no instance did the subjects receive any aid whatever excepting from the moving face of the experimenter and the vibration of the receiver. None of the stimuli, furthermore, was ever used for any purpose in this Laboratory, excepting incidentally, outside the experiments we are discussing here.

Scoring in the case of word lists was made, of course, on the basis of the number of words recognized by the two methods, respectively. In the case of sentence lists, scoring was done on this basis, also, and, in addition, on the basis of whole sentences literally reported. Further comment relating to scoring reports on sentence stimuli will occur on a later page.

Certain records were obtained by the co-operation of a stranger to our cases and to the whole Laboratory situation—Miss Josephine Timberlake. She came into the Laboratory and pronounced the stimuli (sentences) without a prepossession that results like those already obtained must be forthcoming. Her work may be described as a control test.

In the dual stimulation series, the subjects held the receiver of the teletactor system in their fingers and the experimenter held the microphone at the side of his face. In this situation, the subjects can see the speaking face and, and the same time, feel the spoken words and sentences against their fingers. It should be remembered, too, that in the straight lip-reading series, the experimenter always held the microphone in this position, also, so that in all experiments (dual stimulation and single visual stimulation) his face was equally visible.

In both series, too, the current was on so that the teletactor was being actuated by the experimenter's voice. In the single,

visual stimulation series, however, the receiver was not in the subject's fingers. It was lying upon a table, diaphragm upward at the elbow of the observer. Thus, if there was any possibility that an observer with a remnant of hearing could obtain an occasional helpful auditory cue in one series, he should have the same advantage in the other. In fact, he would have a greater advantage from such a source in the straight-lip-reading series; for the receiver was not damped in this situation by contact with the subject's finger. It was, therefore, more audible, to the experimenter at least, than in the dual stimulation series.

RESULTS AND DISCUSSION

Isolated Words as Stimuli. The main results of this experiment are set out in the tables below. In the interest of economy of space, absolute scores in lip-reading and lip-touch-reading are omitted, except in Table III. There are included in Table I only the *ratios* of scores obtained under conditions of dual (tactual-visual) stimulation (Lip-Touch-Reading scores) to those that were made under single (visual) stimulation (Lip-Reading scores). The stimuli in this case were drawn from our list of 200 monosyllabic words already referred to. Sixteen of these ratios were obtained when 50 words were being employed as stimuli; 31 when 100 were being employed, and one ratio was derived from the use of 132 words.

TABLE I.

RATIOS OF SCORES FROM DUAL STIMULATION TO SCORES FROM SINGLE STIMULATION WHEN THE STIMULI ARE SPOKEN ISOLATED MONOSYLLABIC WORDS.

1.—1.87	17.—1.01	33.—1.03
2.—1.53	18.—1.33	34.—1.21
3.—1.35	19.—1.25	35.—1.12
4.—1.15	20.—1.07	36—2.04
5.—1.17	21.—1.43	37.—1.1
6.—1.35	22.—1.29	38.—1.21
7.—2.27	23.—1.44	39.—1.3
8.—1.29	24.—1.81	40.—1.25
9.—1.79	25.—1.56	41.—2.5
10.—1.19	26.—1.49	42.—1.0
11.—1.94	27.—1.48	43.—1.3
12.—1.13	28.—1.49	44.—5.0
13.—0.81	29.—1.87	45.—3.0
14.—1.19	30.—1.06	46.—0.88
15.—1.43	31.—1.07	47.—1.3
16.—1.04	32.—1.35	48.—1.1

Median ratio 1.3.
Median Absolute Scores: Lip-Reading, 29; Lip-Touch-Reading, 40.

Those who are predisposed toward statistical research may inquire, at the outset, (apropos of the records above and similar ones to follow) about group average ratios, mean variations, probable errors, correlations with one thing and another, and the like. This is no place for such activity, for the reason that we *are not dealing here with comparable units.* The description of our subjects or observers on a preceding page makes the last statement sufficiently emphatic. Observers differ widely among themselves in respect to degree of deafness; age of onset of deafness; chronological age; school history; lip-reading ability; temperament and, in all probability, in natural intelligence. Our observers are a group only in the sense that they are together in the Laboratory. In view of their manifold differences, the only comparison we are justified in making is between a given observer's record as a lip-reader and the same person's record in the dual stimulation situation—lip-touch-reading.

No characteristic of the data in the foregoing table can be attributed to aid that the teletactor affords toward making one acquainted with the number of syllables being spoken, because all the stimuli are monosyllabic.

The figures indicate, on the whole, a considerable advantage for dual over single stimulation. The words were interpreted less successfully by straight Lip-Reading than by Lip-Touch-Reading. The median advantage is 30%. There are nine of the 48 cases in which the ratio is under 1.1. Three of these nine records were made by one of the nineteen who participated in this experiment as subjects. This was a young woman 18 years of age who appeared for six experiments of the nature we are describing on December 8th, 9th, 14th, 16th, 17th, 1925, and on May 17, 1926. On her other three appearances, dual stimulation gave her an advantage of 19%, 33% and 43%, respectively. Prior to the first of these six experiments in which she participated, she had worked in the Laboratory as a subject during an aggregate of 138 hours.

The remaining six ratios that are under 1.1 in this list were obtained, no two of them, from the same subject. Their aggregate time in the laboratory, prior to their taking part in these experiments, was 3, 4, 7, 14 and 33 hours, respectively.

Thirty-nine of the 48 ratios in the above table are within five points (a point is 0.1) above and five below the median advantage for dual stimulation that lies, as already stated, at 30%. The median number of aggregate hours of prior Laboratory work, in

these instances, is 76. So far as our present background of experience is indicative, not many fewer than this number of hours of appropriate training can be relied upon to support our general findings.

Sentences as Stimuli; Scores Based Upon Words Recognized. The following Table II contains data that correspond exactly with those in I. Whole sentences, however drawn from the list of 116 already described, were employed as stimuli. The scorings from which the ratios in this table have been derived were based upon the absolute number of words that were recognized by Lip-Touch-Reading and by Lip-Reading respectively.

TABLE II.

RATIOS OF SCORES FROM DUAL STIMULATION TO SCORES FROM SINGLE STIMULATION WHEN THE STIMULI ARE SPOKEN SENTENCES. SCORING BASED UPON RECOGNITION OF WORDS.

1.—0.9*	14.—0.9	27.—1.1
2.—0.97	15.—1.1	28.—0.89
3.—0.8	16.—1.8*	29.—1.3
4.—2.2	17.—1.6	30.—1.3
5.—1.2	18.—1.5	31.—1.3
6.—1.3	19.—1.5	32.—1.3
7.—1.3	20.—1.5	33.—1.1
8.—1.4	21.—1.8	34.—1.1
9.—1.2	22.—1.05	35.—1.1
10.—1.1*	23.—0.99	36.—1.2
11.—1.7*	24.—1.0	37—2.8
12.—1.2	25.—1.1	38.—1.7
13.—1.1	26.—1.1	

Median ratio 1.2.
Median Absolute scores: Lip-Reading, 52; Lip-Touch-Reading, 67.
Grand Total, scoring on Words, Table I and Table II, 86.

In each of two of the 38 experiments from which the data of this table were obtained, the sentence stimuli included 87 words; each of nine, 114 words; in each of five, 252 words; in each of nine, 277 words, and in of the remaining thirteen, 529 words. It has already been pointed out that just above 90% of all these words are monosyllabic; 7.8% of all are bisyllabic and slightly over 2% are trisyllabic.

This table indicates also a considerable advantage for dual over single stimulation. The median advantage is 20%, contrasted

* Ratios marked by an asterisk are between absolute values obtained in the control test, already referred to, that was made by a stranger to the subjects, Miss Josephine Timberlake of the Volta Bureau, Washington, D. C.

with 30% indicated in Table I. The absolute scores, both for Lip-Reading and Lip-Touch-Reading are considerably higher in relation to words that are comprised in sentences than to isolated words. The median values are given in Tables I and II. The higher scores in this case were anticipated at the outset because a sentence affords a helpful context that is wholly lacking in the word standing alone.

The tendency of the context factor should be in the direction of lifting up the ratios also in Table II. But this tendency is doubtless counteracted by the higher absolute scores themselves. For obviously, as the room for improvement in interpretation by the more successful of the methods is narrowed, the *relative* rate of improvement by the less successful method is accelerated, and the gap between the corresponding scores tends to become closed.

Of the ratios in this table, eight are below 1.1. Six of these low records were made by two of the eighteen subjects who lent a hand in this portion of the work. It should be said that one of the six ratios is 1.05. The remainder are 1.0, 0.99, 0.9, 0.9, 0.97 and 0.8. The subject who made three of the nine records below 1.1, in relation to isolated words, is responsible for three entries in Table II, as follows: 1.1, 1.2 and 1.7.

A subject who contributed three of the seven low ratios in the above table (1.05, 0.99 and 1.0) gave us the following ratios in Table I: 1.06, 1.07, 1.35, 1.03, 1.21 and 1.12. At the time these experiments were made, her Laboratory practice had aggregated only 12 to 16 hours. Among all the 35 deaf persons the Laboratory has dealt with in all its relations in the course of the last four years, this one is superior as a Lip-Reader. In her case, when sentences and continued discourse (as opposed to isolated words) are being employed to detect her interpretative ability, there is probably no tool that can importantly supplement her visual perception of a speaking face.

The other subject who contributed three of the seven low figures in Table II is a lackadaisical fellow of good natural capacities who has very poor lip-reading ability. In our tests employing isolated words, his ratios were 1.15, 1.17, 1.35, 1.35, 1.53 and 1.87. Prior to the earliest test, he had had Laboratory training aggregating 130 hours.

Of the 38 records in this table, 36 are within the limits of five points above and five below the median of 1.3, which suggests a median advantage of Lip-Touch-Reading over Lip-Reading, of

30%. The median number of corresponding aggregate hours of training, prior to the earliest of these dual stimulation experiments, is 86. This figure may be misleading when compared with the corresponding median in relation to Table I, which is 76. This difference between the two, however, is not quite so much as it appears to be, for the reason that the aggregate number of Laboratory hours spent by our subjects, prior to our use of sentences as stimuli, includes all the time that they spent with dual stimulation by isolated words. This time alone amounts to from one to six hours. In a few instances, moreover, other Laboratory practice intervened between the two sets of experiments.

INSTRUCTIONS TO SUBJECTS

The instructions given to subjects, when sentences were about to be pronounced as stimuli, were complicated. They were required:

1. To write down, if possible, the whole sentence as soon as they should feel it and see it upon the experimenter's face.
2. If they were unable to do this, they were instructed to make a dash on their pads for every syllable in the sentence.
3. Any word that they might recognize, they were to write in its proper place among the dashes.

Obviously these instructions demand a much more complicated reaction than is required in the isolated word situation in which the subject wrote a single word or a dash. In the whole sentence situation, the subjects were under the necessity of attending to several things: the sentence as a whole; each word individually and finally, the number of words in each sentence, so that he should be able to "dash it" in the event of his being able to report only a part of it or none of it. The situation is further complicated by the fact that if a subject has recognized but two words, for instance in a five word sentence—the second and the fourth—he must try to place the words in their proper places: that is, between the first and the third dashes, and between the third and fifth dashes, respectively. The division of attention that all this entails might be expected to produce erratic behavior in both the Lip-Reading and the Lip-Touch-Reading series. As a matter of fact, it seems not to have done so. For, as has been stated already in Table II, 36 of the 38

ratios (over 94%) are within a range of five points on each side of the median. Whereas, in Table I, 39 of the 48 ratios (just above 81%) are within the same range.

Sentences as Stimuli; Scoring Based Upon the Number of Sentences Literally Reported. Reactions in the sentence stimuli situation were scored, not only upon the basis of the number of words they recognized, but upon the number of sentences they interpreted. In this connection, a rigid criterion was arbitrarily adopted. Every word must be recognized and written in its proper place. A single transposition of words, or an omission, automatically threw out a whole sentence as incorrect. It is not surprising, therefore, that scores on this basis are lower and more erratic than those based upon the number of words recognized.

There were thirteen reports on 58 sentences aggregating 529 words; eight on 30 sentences aggregating 266 words; six on 28 sentences, 241 words, and eleven on 10 sentences, 114 words.

Table III indicates there were two instances in which subjects registered zero in both Lip-Reading and Lip-Touch-Reading. One of these subjects recognized 15 and 28 words by Lip-Reading and Lip-Touch-Reading, respectively, and the other 20 and 32. Neither of them reported a literally correct sentence. But for transpositions, one of them would have scored *two* and *three* sentences, and the other *three* and *five* by the two methods, respectively. It is highly probable that they understood these sentences perfectly. There may be many other cases among the 38 represented in the table in which subjects grasped more sentences than their credit indicates. On the other hand, there is no denying the fact that what has sometimes been a correctly interpreted sentence may be, for the subject, merely a string of words—at the moment of writing them, at least. Furthermore, it is probable that there were instances in which the recognition by Lip-Touch-Reading of but one word more than by Lip-Reading may have turned the scale for that method of interpretation. The facts might have been established by requiring a pantomine in connection with each report. There was no recourse to such a measure. The figures in Table III represent both absolute values and ratios, not ratios alone as in the preceding tables.

TABLE III—REPORTS ON THE BASIS OF LIP-READING AND LIP-TOUCH-READING, RESPECTIVELY, WHEN THE STIMULI ARE SPOKEN SENTENCES.

Scores Based on Number of Sentences Literally Reported.

	Number of sentences	Correct By L. R.	Correct by L. T. R.	Ratios
1	58	3	2	0.6
2	58	1	3	3.0
3	58	13	19	1.46
4	58	3	16	5.3
5	58	2	19	9.5
6	58	5	20	4.0
7	58	32	48	1.5
8	58	13	30	2.3
9	58	9	29	3.2
10	58	7	6	0.0
11	58	31	33	1.06
12	58	13	16	1.2
13	58	5	12	2.4
14	30	3	6	2.0
15	30	3	3	1.0
16	30	13	15	1.15
17	30	6	20	3.3
18	30	5	21	4.2
19	30	5	22	4.4
20	30	25	26	1.04
21	30	5	6	1.2
22	28	1	2	2.0
23	28	3	5	1.66
24	28	3	9	3.0
25	28	14	19	1.35
26	28	2	5	2.5
27	28	2	1	0.5
28	10	9*	6*	0.66
29	10	0*	4*	
30	10	3*	4*	1.3
31	10	0*	1*	
32	10	2*	4*	2.0
33	10	1	3	3.0
34	10	2	4	2.0
35	10	2	3	1.5
36	10	1	3	2.0
37	10	0	0	0.0
38	10	0	0	0.0

Median ratio, 2.0.
Median absolute scores
Lip-reading, 3.
Lip-touch-reading, 6.

The grand total of records in Tables I, II and III is 124. Of these, 108 are positively in favor of Lip-Touch-Reading.

* The digits marked by an asterisk indicate scores obtained from the control test in which Miss Josephine Timberlake of the Volta Bureau, Washington, D. C., acted as experimenter.

An inspection of the foregoing table will show that there are only nine ratios below 1.1. Whether we include or exclude the two cases in which no score was made by either Lip-Reading or Lip-Touch-Reading, the median ratio is 2.0. It will be recalled that the median ratios computed from Tables I and II are, in each case, 1.3. The records in Table III are comparatively erratic, due to causes that have been discussed herein. Only ten of the 38 ratios lie within the range of five points on each side of the median. This is slightly above 26% of the total as compared with the corresponding 81% and 94% in Tables I and II, respectively. The median aggregate number of Laboratory hours corresponding to these records is 86. Fifteen ratios are below 1.5. The corresponding median hours is 43. The twenty-three remaining ratios are above 2.5. The median number of hours in the Laboratory, corresponding to these ratios, is 110.

Owing to the almost uniform syllabic composition of the sentence stimuli that were employed in this section of the work, there is no more than a negligible chance that counting the syllables could give a subject the slighest clue to the sentence that was being spoken.

The data presented, to this point, clearly indicates an advantage for Lip-Touch-Reading over Lip-Reading. But why? Does the tactual stimulation contribute in its own right or otherwise?

Tactual Stimuli as Mere Distraction

The question above will be at least partially answered by a discussion of the following query. Does the tactual stimulation reenforce visual stimulation in the process of interpretation merely because it is an accessory and distracting factor? Some people declare that they can study in the midst of slight confusion more successfully than in a quiet place. But the question, as bearing upon the present work, implies a bare guess without a particle of foundation. The Laboratory has made preliminary experiments that have been aimed at the question. The *modus operandi* was as follows:

An experimenter (in this case a Professor of Spoken English in Smith College who was visiting the Laboratory) pronounced a list of sentences for the purpose of determining the accuracy of a deaf subject at "straight" lip-reading. There were 50 sentences in all, divided into five short series of ten each. When the first short series had been pronounced, a second was presented, but

with a difference: in this case, the subject held in her fingers the receiver of the teletactor system, and a second experimenter, out of sight at the microphone, pronounced other sentences. Thus, while the subject was observing the face of the first experimenter and was attempting to lip-read, she was receiving tactual impressions of the second experimenter's sentences. By vision and by touch, respectively, she was simultaneously receiving two sets of sentence stimuli that were different and unrelated to each other. If tactual stimuli, merely *as distraction*, are positively effective in relation to interpretation, the subject should have made a better record in those alternate short series in which she was impressed by simultaneous visual and tactual stimuli, than in the other series in which she was observing the speaking face of the first experimenter, but was receiving no tactual stimulation. But the results were actually the reverse. She made a better record without the distraction of tactual stimulation, as Table IV indicates.

TABLE IV—RECORDS WITH TACTUAL DISTRACTION AND WITHOUT IT.

A. 100 sentences as stimuli containing 795 monosyllables, 69 bisyllables and 17 trisyllables.

	Prof. A experimenter	Miss L experimenter
With distraction	34%	32%
Without distraction	35%	41%

B. Recognition of words in above sentences.

	Prof. A experimenter	Miss L experimenter
With distraction	41%	30%
Without distraction	49%	47%

The subject whose reactions furnished these results was finally tested to obtain her record as a straight lip-reader and as a lip-touch-reader, with the following results:

100 isolated words—Lip-Reading, 39%. Lip-Touch-Reading, 51%. Ratio, 1.3.

436 words in 50 sentences—Lip-Reading, 48%. Lip-Touch-Reading, 61%. Ratio, 1.27.

Up to this time, the subject had spent an aggregate of 30 hours in the Laboratory. Each successive Laboratory period had been divided approximately as follows: Instruction in enunciation, 10-15 min.; drill on the patterns of sentences as felt, 15-20 min. The balance of the hour was spent on continued discourse: reading aloud in unison with the experimenter's voice as felt. She is a very intelligent person of about 25 years of age. Her facility in general conversation would probably rank her as a *very good* lip-reader, although the test figures above mean less than that. There are records of two audiometric tests in her case. One makes her residuum of hearing 50% in each ear. The other makes it 40% in one ear and 45% in the other. The condition is described as congenital.

It may be good, as David Harum said, for a dog to have a few fleas—because of their mission as distractors from the idea of being a dog. But there is no evidence, in these preliminary figures, that tactual stimuli in our Laboratory situation perform an analogously useful distracting function for the deaf lip-reader. Further work on this topic is in progress; and it should be said, in this connection, that to the present, we have no evidence upon the distraction hypothesis contrary to what is suggested by the figures above.

On the other hand, the work on homophenous words already referred to and our experiments at comparing vision alone with touch alone as means for locating accent, (see above) afford indubitable proof that the tactual sense, in its own right, does make some positive contributions toward interpretation that eyes alone cannot make.

AN IMPORTANT QUESTION

It is only when one is in contact with the teletactor that one enjoys a profit from having trained in its use? At present, we have no direct answer to this question. No such answer to the query can be had till a considerable number of subjects shall have been harnessed to the teletactor continuously during several years in succession, while, at the same time, they are having conventional instruction in lip-reading, and until they shall have been compared at the beginning and at the end of the period with a comparable group who have, all the while, had parallel conventional instruction in lip-reading. Even so, iron clad conditions for such a test would be very difficult to obtain and experimenters

would undoubtedly have to rely, to a great degree, upon the testimony of intelligent deaf folk who have trained for a long time in the use of the teletactor.

A priori a positive hypothesis in this relation is not unbelievable. At any rate, there is probably no normally hearing person but who believes that his acquaintance with even the conventional lilt, movement or pattern of speech helps him to get the meaning of spoken language. One of our difficulties with foreign speech, in addition to our scanty vocabulary, is just our unfamiliarity with its pattern, which normally cooperates with other spoken language factors to convey meaning. What we call "acquaintanceship with pattern" is probably, in its last analysis, a very great complex of incipient motor reactions that have been conditioned to auditory symbols, and, incidentally, to printed symbols on the pages of our books also. Now we have fully enough demonstrated that this "acquaintanceship" is made by our deaf cases through the sense of touch and the hypothesis is that the corresponding "incipient motor reactions" may be conditioned to visual symbols on the speaking face. When then the lip-reader catches facial signs of meanings, a host of meaningful conditioned motor reactions that correspond to his laboratory acquired tactual patterns, come to his aid.

But this is not the only way to answer the question. In the Laboratory, we have demonstrated (in re recognition of words) a median superiority of lip-touch-reading over lip-reading of 30%. In respect to the recognition of whole sentences, the median superiority runs to 100%. Let us assume, if you please, that in the schoolroom, this superiority will be reduced two-thirds. Even so, the expedient of lip-touch-reading will greatly speed up the processes of learning and, consequently, the range of information, because the pupils can the better understand what is being said to them. Only this, therefore, remains to be observed: the broader and fuller one's information, the greater one's facility at jumping at meanings when signs are caught upon the face of a speaker. Thus the effect of laboratory or school training may carry over to a situation in which the lip-reader is not in contact with the teletactor.

In concluding our remarks upon this point, it is worth keeping in mind that there is a distinct possibility that an easily portable teletactor may sometime be constructed so that, wherever a lip-reader may be, he may have the direct advantage of its use.

SUMMARY AND CONCLUSION

1. When deaf subjects feel speech in their fingers through the teletactor and, at the same time, see it upon the face of a speaker, the combined tactual-visual impression enables them to interpret speech more fully and accurately than does the visual impression alone, as in straight lip-reading.

2. The median advantage (48 cases) afforded by the combined stimulation over visual stimulation alone is 30%, when the stimuli are isolated monosyllabic words and scoring is made on the basis of the number of words correctly reported by the subject.

3. When whole sentences are presented as stimuli and scoring is upon the basis of the number of words correctly reported, the median advantage (38 cases) is 30%.

4. When whole sentences are stimuli and scoring is upon the basic of the number of whole sentences literally reported, without even the transposition of words, the median advantage of combined stimulation (38 cases) is 100%.

5. The advantage of dual stimulation over single visual stimulation does not appear to be due merely to a distracting effect of dual stimulation.

6. It is impossible that the advantage is due, in our situation, in any degree whatever, to the fact that the teletactor enables the subject to count the number of syllables being spoken, for, in the isolated word tests, all words were monosyllabic and over 90% of the 1,026 words in our sentence stimuli were of one syllable. Moreover, over 71% of the sentences contained 10 syllables each, over 16% have nine syllables each, and over 5% contain eleven each. The remainder are of eight and twelve syllables each.

7. Other studies have shown that the deaf are able to count syllables more accurately by touch than by lip-reading; that they may be expected to locate accent to an accuracy of more than 90%, and that they locate it more accurately by touch alone than by lip-reading alone. A study of reactions to 103 groups of homophenous words, furthermore, has shown deaf subjects to be much more accurate in discriminating homophenes by touch alone, than by lip-reading alone.

SUPPLEMENT

A. List of words from which stimuli were selected for comparing efficiency in Lip-Reading with efficiency in Lip-Touch-Reading.

foam	farm	bear	share
harm	bee	pie	pear
see	sew	bathe	bar
bow	by	let	lathe
my	me	ham	bet
be	came	reap	ram
rain	race	rail	heap
case	rope	hose	hail
hope	hill	bay	rose
rill	me	ream	ray
fee	far	rice	beam
mar	hole	mock	mice
coal	call	cave	rock
hall	day	rook	rave
whey	why	sharp	cook
die	cave	keep	carp
gave	gape	coke	sheep
cape	beef	palm	poke
reef	rake	pool	calm
bake	bow	cone	cool
how	hay	fir	pone
boy	who	same	sir
shoe	shop	joy	fame
hop	shy	tam	toy
home	pair	pie	jam
thy	thine	chill	jest
line	knead	queer	quill
read	real	lice	cheer
kneel	lark	vile	vice
shark	shame	go	lisle
lame	hair	same	so
rare	row	get	game
hoe	pipe	lay	let
ripe	reach	that	gay
peach	ride	kiss	cat
tide	to	thin	this
rue	moon	pen	pin
June	Jew	door	then
mew	new	bet	bore
chew	chum	wave	debt
numb	mouth	roar	rave
south	soap	way	wore
mope	sight	rife	ray
might	mop	white	wife
sop	you	rye	right
hew	hard	heap	why
yard	yell	rate	reap
sell	set	ship	hate
yet	jar	lie	lip
lie	test	tar	shy

B. List of sentences from which selections were made to serve as stimuli. Some indication of the pattern of the sentences

as spoken is afforded by various signs. Hyphens indicate quickly spoken words. Primary and secondary emphasis are indicated by " and ' respectively.

They both' seem to-be so" far" away.
They may' be on-the-same"- ship" with you.
They are on"-the"-way" to-the shoe' shop.
They say the ship is safe' in-the-bay".

I will show'-you the-palm" by-and-by.
I bought five' pies' at-the-shop" for you.
I shall-buy both-the-pipe' and-the fife'.
I will go now' to-pay for-the-farm".

Why do-you-go-to-the-cave' with them?
Will you give-me-a-cup-of cof'fee?
Will you' go to-the-game with-the boy?
Will you show me the-way" to-the cave"?

I' believe they will refuse" to-remain.
Why' do-you-wish to remain" on the-ship?
Do you' remember what became" of-them?
You must' remember to-make-a report.

We shall be so' ha'ppy to have you come.
I wish you would' help-me move the palm.
They may all' remain with-you for-an hour.
I heard about it before" they-came home'.

I" have not written to-him' for some time".
You will hurt your eyes' if-you read" so-much.
That' is not the-right way" to-the river.
They have raised the rent' of-the house today".

I wish" you would'-read the rest" of-it now.
Where" did-you-buy the nice rug' for-your-room?
I hope'-it won't rain" before-we-get-home".
It is a long" way" to-the rain' bow's end.

I cannot remember how' many" there were.
Are you quite' sure that-this-is-the-right" car"?
You-will hear from-me' before very long.
I am sure" that-it-was more' than-an-hour.

They will surely' be quite through by-that" time.
How far is it from there" to-the-long'-pier?
I shall-go more frequently' from now" on.
Did-you make' this frame or did-you buy" it?

Will-you please' buy a-loaf-of-bread for me?
She wore-a large brown' hat with-a broad" brim.
That is too high priced for my' pocketbook.
Bring me' the-book after you have read-it.

I am quite' sure there-were-a-great" many more.
We-have-been-out there a great' many' times'.
She spends a-great" deal' of-her-time reading.
Can-you'-tell-me' now where the grape'-fruit grows?

Bring me' the-book after you have-read-it.
The bird is-on-the-branch of the fruit' tree.
I-was surprised' to-see-them on Friday".
The-boys have all been fishing' in-the-brook.

The farmer has raised-a-fine' crop-of-grain.
She-was very' cross when I crit'icized her work.
They live in-the-brown' house across the-way.
There were-a-great' many nice grapes on our" vine.

Have you ever seen-a-field of flax' in-bloom?
Will-you-please' help me to plant the rose"-bush?
You are much' too slow to-finish'-in-time.
Will you take-a sleigh'-ride with-me-today?

I saw-a fleet of ships' in-the-harbor.
Do you prefer the-black' or the-brown" frame?
Are you' going to-take-a-part in-the-play?
Myrtle wore her new blue hat' to-the-play.

What-is-the-price" of-the black' broad-cloth cloak?
Will-you-buy a globe' for me when-you go?
He can' not see-to-read' without his glasses.
There is-a hall' clock in-the other room.

He-lost his glasses' on-the-way to-the-club.
Please' show-me the-short" way to-the-club-house.
Can-you-tell-me at-what-time the bank' closes?
Did-you-speak to-the-clerk' about the-gloves?

If possible' let-me-know tomorrow".
I am afraid he knows nothing' about" it.
We-have-had no' news since last" November".
They-will-arrive here' on November ninth".

Do you' know the-number of-their new" room"?
You will need more new clothes' if-you-go south".
Give-me-the note' that-he-brought-you tonight.
Did-you-notice the name' on-the-note book?

Do you know the-name-of-the inn' in Lynn"?
Buy-the-pin in-Japan" or in-Berlin".
Yes' you-may-keep whichever one you please.
Nothing can-be-done now' about the-name".

If I were in-your' place I-should-go now".
Then come to us tomorrow' if-you-can.
Is this the-best' way to-the-road-side Inn?
Shall-we-go-to San Francisco today'?

Can-you-play-a tone' on-the-piano?
The-house-and-barn belong to-my father'.
I found the-pine cone in-the-near-by woods'.
I prefer' to-go in-the-afternoon".

What kind-of-grain' do-they-raise on their" farm?
Do-you-know how much he paid' for-his-cane"?
If I had known'-of it I should-have-gone".
Do you insist' that-I-must-go-alone"?

I mean to-go-down town' this-after-noon.
I mean to-ask'-her if-she-has-seen-them.
We-should-be-much pleased' to-have-you join" us.
Do-you-think he-can-earn' as-much-as that?

Did-you-affix your' name" to-the-paper?
There-was-no sign' of-rain when we" left home.
You-must return' the-book" this afternoon.
He-did-not-learn his lesson well' today".

She is sure' that-she-lost-it on-the-way".
He-lost-it last time he visited' here.
It-was week before last' when he-was-there.
It-was half-past four' when-they arrived here".

This-is-the-worst storm' we-have-had" here.
The-crew' was saved when-the-ship sank today".
Have-you-seen-the raft' float on-the-river"?
I wish we-had-saved" some-of-the-fruit.

My brother's' name was last" on-the-ship-list.
Who-is-going east' with-you this summer?
The-boys" are playing out-in-the hay" loft.
She slipped on-the-floor" and broke her left wrist'.

The-list-must-be ready' by next Monday".
It-will-be best" to-go on-the-fast train.
I wrapper-the-book in heavy brown paper'.
It must-be-done' by Monday afternoon".

AN EXPERIMENTAL STUDY OF THE SLEEP OF ATHLETES

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Our common language has two ways of describing the way in which sleep may be enjoyed. There is, first, the belief that one can and sometimes does go to bed and "sleep like a log" for a full eight or ten hour period. It is said, for example, that extreme fatigue may be followed by a motionless rest that will "knit up the raveled sleeve of care" and bring the individual forth to a new morning and to new levels of energy. This is the way small infants are said to sleep, and it is a matter of plain observation that they do remain almost motionless for considerable periods of time. It is also said that this is the way invalids sleep, and one draws the inference that absolute motionlessness is the only way to gain a real rest. Infants do move, however, and so do invalids, and any half hour's observation of a sleeping adult will show that he is almost constantly in motion. But in these cases our common language says that the infant, the invalid, or the adult is a restless sleeper, and the implication is that restlessness in sleeping is more or less of a disadvantage or that it is a habit that robs one of his real rest. We frequently say that we have "tossed all night," and it is with the idea of "tossing" that we associate almost every form of movement during the night. It is by no means obvious, however, that motionlessness during sleep is the ideal way to sleep, and neither do we believe that a great amount of restlessness yields the ideal conditions for recuperation by night.

The older methods of studying sleep were not adequate to answer the questions one might raise about the optional amount of motion during the night. Up until two or three years ago, the standard method consisted in finding out how far a ball of a given weight must be dropped before the sound would awaken the sleeper. This was said to be a measure of the depth of sleep, for if the ball has to drop from a great height in order to make sufficient sound to awaken a man, he must be sleeping more deeply than he is when the ball has to drop but a foot or two. But such a measure of the depth of sleep is by no means a measure of the extent to which the period of sleep is giving real recuperation.

Consequently, a new method of studying sleep has been recently devised at the Mellon Institute under the direction of H. J. Johnson, senior fellow on a research program supported by the Simmons Bed Company. It is this method which has been used in our studies on athletes at the University of Illinois.

Underneath the bed occupied by each of the subjects in our experiments there is hung a recorder which automatically registers every movement made by the sleeper during the night. Upon a frame hung from the bed is a constant-speed motor of the type commonly used in electric phonographs. This motor drives a band of paper at the rate of about one centimeter per second past a pair of writing points. One of the writing points is activated by a timer that is nothing more than an alarm clock upon which a wheel with a series of small contact points have been put in place of the minute hand. The contact points are so arranged that a mark is made upon the moving band of paper every five minutes during the night. These marks form the time line. The second writing point is connected with the springs of the bed in such a way that any change in the level of the mattress appears as a "sleep curve" or a "sleep line" on the paper just above the time line.

Before getting into bed each night the subject winds the alarm clock, makes a note as to his time of retiring, records any other items that may have a connection with his sleep period, starts the motor and climbs into bed. From that moment until he arises in the morning to record the hour of awakening and turn off the motor, every movement that he makes appears on the record. The subjects in the experiment up to the present time have been members of the 1927-1928 and 1928-1929 football teams, members of the 1927-1928 and 1928-1929 basketball teams and such other members of athletic teams, principally track men, as were available between the football and the basketball seasons. The results in our own experiments bear comparison with similar results gained by Johnson at the Mellon Institute and Anderson at the Child Research Center of the University of Minnesota.

The first thing of interest in these experiments is the determination of the period of average restlessness during the night. No persons have been found who go to bed and "sleep like a log." The longest period of absolute motionlessness we have found lasted for sixty-five minutes. There are a few other periods of forty-five minutes or longer, but the most of the intervals are much shorter

than this. The period of average restlessness for all of the men engaged in this experiment stands at a little over twelve minutes. This means that, on the average, each of our men made some movement of his body at least once every twelve minutes during the night. It may not be that the subject moves his whole body, but the results do mean that some movement of a major degree occurs, on the average, every twelve minutes. There are, of course, certain large individual differences. The most restless of the men with whom we have experimented moved, on the average, at least once every seven and one-half minutes, while the heaviest sleeper moved at least once every sixteen minutes. These results are directly comparable with those obtained by studying the sleep of small children at Minnesota and the sleep of adults and of hospital patients at Pittsburg.

But the average period of restlessness was not our main objective, since this has already been established. We were searching, instead, for the effect of heavy exercise on the sleep of our subjects. In keeping with popular opinion we should have found, perhaps, that, on the night after a hard basketball or football game, the athlete would go to bed and sleep like a log, that is, sleep without very much bodily movement. The long periods of motionless rest mentioned above were periods which occurred under these very conditions. That is, a long period of motionlessness is more apt to occur after heavy exercise than at any other time; but this fact does not tell the whole tale. The full story is told only when we get a report from the individual himself as to his condition on the morning after such motionless sleep and after we gain from him some objective records of his performance in simple tests that test his quickness and muscular control. When we gain this information we see the full significance of his restfulness. Motionless sleep is not restful sleep. It does not lead to the kind of recuperation which the athlete is in search of. This is gotten, strange to say, by the men who go to bed and who move more than their normal amount during the night. That is, there appears to be a type of increased restlessness which is actually more conducive to recuperation after heavy exercise than the so-called log-like sleep. Our records show that heavy exercise will result, on the average, either in a two-minute decrease of the average period of restfulness or in a four-minute increase of the average period. The men who yield an increase, that is, the men who do not move so often, are not as rested the next morning, and neither do they

appear to be so efficient in small tests of skill, as the men who yield a decrease in average period of motionless, that is, who move more often after extreme exercise.

These facts suggest a new statement of the functions of sleep, a statement that sounds strange at first but which appears simple and plain after it is fully understood. Sleep is, or should be, a period of recuperation. Recuperation takes place when the blood stream has a free and uninterrupted access to all parts of the body and especially to those that have been used most recently and most strenuously. It is easy to see that if a man falls to sleep and remains motionless on a part of the body that has been heavily exercised, that part will not receive an adequate supply of fresh blood. Sleeping like a log, then, means becoming more or less loggy because of improper sleeping conditions. The increased restlessness of the man who has exercised heavily appears to be nature's way of seeing to it that all parts of the body get their proper amount of rest by being on the top side as often as possible.

WHAT SHALL THE SUPERVISOR DO?

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Recent literature on supervision makes frequent reference to "principles of supervision," but there is a tendency for these principles to conflict. Differences in point of view are recognized by Knight when he says: "One type (of supervision) places the responsibility for leadership on the teacher. It is highly improbable that much good is derived from putting on a drive in spelling at one time, of testing and plunging in arithmetic at another, of stirring up enthusiasm and anxiety about art at another and of standing by to slowly watch these drives die like waves after a storm. Such procedure is certainly not constructive supervision. What we want is perpetual guidance. A supervisory technique which cannot be maintained as a permanent aspect of the life of the school warrants little confidence." "One theory would suggest that a school is analogous to a soviet of teachers. The other would suggest that a supervisor and his teachers are analogous to a master surgeon directing the work of well equipped internes and nurses."[1]

Hudelson describes two kinds of supervision, the didactic and the experimental. Under the didactic, "the supervisor simply tells the teacher how to teach. What he tells he probably received from his supervisor who in turn hear it from his. If he has abundant experience, if he has common sense and if he is a shrewd observer, many of his opinions will probably be sound; but those that are wrong will be as wrong as sin. He not only tells one teacher how to teach, but he tells several teachers and he tells them all the same things! "Under the experimental type of supervision, the supervisor provides the teachers with techniques whereby they may attempt to solve their teaching problems experimentally."[2]

The statements just reviewed are illustrative of the disagreement concerning the basis for supervisory procedure. Shall initiative for improvement of teaching rest with the supervisor or

[1] F. B. Knight, Scientific Supervision, *Journal of Educational Research*, 16:1-15.

[2] Earl Hudelson, Experimental Supervision, The First Yearbook of the Conference on Educational Method, pages 208-215.

the teacher? For example, shall the supervisor visit the teacher, find out what she is doing, and work in detail on making improvement, or shall the supervisor create the conditions for self-improvement on the part of the teacher? Shall the supervisor aim to see that all teachers employ the same method, or is it better for the supervisor to give attention to the problem of developing initiative and originality? Must distinctions be made in principle between supervision of general subjects, such as reading and arithmetic, and supervision of special subjects, like art and music? What differences, if any, exist between elementary and secondary supervision?

PROCEDURE

There was no thought of attempting to answer these questions in this study. It was felt, however, that it would be helpful to compare the attitudes of the various groups of supervisors, together with those of specialists in school administration, toward certain principles which might be a basis for supervisory procedure.

From an interview study of the practices in the ten Minnesota school systems visited, a number of varying tendencies were found. These were embodied in statements which were augmented by others derived from various sources. There is no claim that the list of statements is comprehensive or that it includes the "right" principles. In case the statements on the form did not describe an individual's view, it was suggested that he fill the blank spaces on the form with the principles to which he did subscribe. Very few such additions were made. When made, they were in almost every case applications or restatements of the items on the form.

The results of the inquiry as here reported (Table I) are probably a measure of the extent to which individuals within the various groups agree to the statements on the form. These groups may approve many other principles not found in the list. If, however, the statements found in the form are not descriptive of the viewpoints of the various groups, this fact has not been indicated in the replies to any significant extent.

VIEWPOINTS OF SPECIAL SUPERVISORS

It will be noticed that the four groups of special supervisors are in substantial agreement that it is the supervisor's function to

visit the teacher and assist with the detail of teaching procedure. They also agree that in this work the supervisor should take the initiative and see that certain objectives are attained. Music and physical education supervisors are least enthusiastic about stimulation of teacher effort through study and experimentation. Likewise, music and physical education supervisors, in substantial numbers, believe that their function is to see to it that their subjects are taught in accordance with certain standards and methods. Approximately equal percentages believe that their function is to develop originality and initiative. In general, it may be said that the majority of those supervisors do not believe that much initiative for improvement of teaching rests either with teachers or heads of departments. They have little approval to offer for the policy of having the supervisor visit only "on call." They agree in refusing to assume teachers to be highly trained specialists who can direct their own work without detailed supervision. At the same time they fail to see in the variety of subjects any great obstacle. On an average, about 30 per cent of these special supervisors believe that conformity to a particular method is essential in the teaching of their subject. It is worthy of note in this connection, that only 3 per cent of the superintendents in these school systems attach similar importance to conformity to a particular method in these same subjects. Experts in administration and supervision likewise attach little importance to conformity to method.

General Supervision

Principals seem to have less faith in conformity to certain methods than the special subject supervisors. They give higher rank to stimulation of study and experimentation. Superintendents seem to have less approval to give for study and experimentation than principals. Perhaps the word "experimentation" in this statement is responsible for the small number of superintendents who subscribe to it. Only physical education supervisors subscribe to this statement with less frequency than do superintendents. On the other hand, nearly half of the superintendents believe that originality and initiative on the part of teachers is more important than method. Conversely, few of them believe that conformity to method is essential. Development of individuality and initiative may be an ideal recognized by these superintendents but not achieved, either because of lack of ways and means or because of the fear of the consequences.

TABLE I—COMPARING THE PERCENTAGES OF VARIOUS GROUPS OF SUPERVISORY OFFICERS WHO SUBSCRIBE TO CERTAIN VIEWPOINTS IN REGARD TO SUPERVISION.

Statement	Per cent*						
	1	2	3	4	5	6	7
It is the supervisor's function to visit classes and confer with teachers concerning the detail of teaching method	47	56	54	70	52	53	44
The supervisor should take the initiative in the work of improving instruction	50	52	60	58	58	69	60
The responsibility of the supervisor is to see that certain definite objectives are attained in instruction	50	60	68	86	84	78	68
The chief supervisory function of the supervisor is not to show teachers how to teach their subjects but rather to stimulate effort on the part of teachers in improving their own teaching through study and experimentation	31	52	75	88	68	41	30
Initiative for improvement of instruction rests primarily with heads of departments	15	18	8	18	32	32	30
Initiative for improvement of instruction rests primarily with teachers	19	20	17	21	28	6	20
The supervisor should extend assistance chiefly "on call," that is, help those who ask for for assistance	7	32	7	19	18	20	10
The supervisor should assume teachers to be highly trained specialists who are competent to direct their own work without detailed supervision	4	2	18	14	.....	.....	3
Detailed assistance to teachers impractical because of the variety of subjects offered	3	4	23	12	14	5	6
Conformity to a particular method is essential	3	6	.....	.....	14	30	28
Originality and initiative on the part of teachers is more important than uniformity in method	44	68	.....	.....	66	39	40
Number included	120	56	80	150	55	75	54

* Key to classes:
1—Superintendents.
2—Specialists.
3—High school principals.
4—Elementary school principals.
5—Art supervisors.
6—Music supervisors.
7—Physical education supervisors.

† For more complete discussion and presentation of data, see "Organization and Administration of Supervision," Northwestern University Contributions to Education, No. 1, Public School Publishing Company, Bloomington, Illinois, 1929.

SECONDARY SCHOOL SUPERVISION

Very small differences are shown between the viewpoints of elementary and high school principals. It is true that only two-thirds as many high school as elementary school principals subscribe to the statement that it is the principal's function to visit classes and confer with teachers concerning the detail of teaching method. On the other hand, a slightly larger percentage of high school than elementary school principals believe the principal should take the initiative in improving instruction. High school principals seem less concerned than elementary school principals about the attainment of definite objectives. To an even less extent than elementary school principals the high school principals assume that initiative for improvement of instruction rests with teachers. A smaller number of them believe that the principal should visit "on call" only. A slightly larger percentage of high school principals see an obstacle in the variety of subjects. Likewise, in larger numbers they assume teachers to be highly trained specialists competent to direct their own work without detailed supervision. However, the differences are probably too slight to be significant. There may be great differences between elementary and high school supervision, but such differences are not reflected in the reactions of the principals who are now doing the supervisory work in these schools.

Suprintendents were asked to check the statements separately for the special subjects and separately for elementary and high schools. In general, they checked all columns the same way, indicating in no way that differences existed in principle between supervision in different schools or subjects.

VIEWPOINTS OF SPECIALISTS

Judgments of specialists seem to differ very little from those of principals. Greatest differences exist between judgments of special supervisors and all other groups. One or two of the specialists returned the forms without checking them with the comment that they were unable to express their views on the form. One stated that he could not check the form "without restricting his views." This, of course, was expected. For this reason blank spaces were left, with the caption, "Others, name them." In view of the expressions to the effect that the statements on the form

did not describe all possible views, it was thought that perhaps a considerable number would add other items. In all, only 18 specialists added items to the list. In most cases these were comments concerning items already found in the list of statements. For illustrative purposes the nature of such comments is here discussed. One authority points out that all supervisory procedure should be tested experimentally. Several seem to believe in greater initiative for teachers but see a number of difficulties in the way of realization. "Originality is desirable provided it leads to desirable ends." "Many teachers should but can't take initiative in improving their teaching because of lack of training." "We dare not wait for calls from teachers." "In better cases initiative may rest with teacher." "In worst cases explicit directions must be given the teacher." One authority believes a general supervisor in high school to be impractical because of the variety of subjects. Another questions the feasibility of detailed supervision in high school. Some emphasize "co-operation," "joy in work," "research," "individual differences." Finally one specialist states that "all the generalizations are wrong, including this one."

INFLUENCE OF THE TEACHER'S TRAINING

In these various comments the feeling can be discerned that the principles subscribed to and procedures followed may be determined to a great extent by the qualifications of the teachers supervised. It is possible that (temporarily, at least) with untrained teachers it may be necessary to prescribe methods in detail and "show teachers how to teach." Highly trained teachers, however, may demand an entirely different supervisory procedure based upon a different concept of the supervisor's function.

SUMMARY

A majority of all types of supervisory officers subscribe to the principle that it is the supervisor's function to take the initiative in instructional improvement, to visit teachers, assist with the detail of classroom procedure, and see to it that certain objectives are achieved. Only a small minority believe in those principles which leave the initiative with teachers. They disagree widely over the desirability of experimentation and originality in method. Special subject supervisors tend to emphasize the importance of conformity to method while principals put a larger premium upon originality and attach a greater importance to experimentation.

The literature, the opinions of experts canvassed in the present study, as well as a study of the judgments of supervisory officers of various kinds, indicates a great difference of opinion concerning the role which the supervisory officer is to play in the improvement of instruction.

It is not, of course, proposed to determine the principles under which supervision should be organized. It is pointed out, however, that in these school systems teachers are being supervised by persons with widely different concepts of the function and purpose of supervision. It may be that a fifth grade teacher who is free to use any method she chooses in reading; is held rigidly to a prescribed method in music. The method used in reading may be diametrically opposite to the one employed in music. For all we know, they may be entirely opposite in educational outcomes. It is difficult to see how a co-ordinated educational program can be carried out under these conditions. It seems that one of the important problems of the superintendent in supervision is leadership in the definition of a set of principles outlining the functions of supervisors. Such principles might set forth also the policy of the supervisory staff with reference to latitude granted and responsibilities assigned to various members. Such principles, in light of the above facts, must be formulated with proper consideration of the instructional objectives selected and the outcomes desired for the several school subjects and activities. These principles and the procedures based upon them may be effected also by the training and ability of the teachers supervised.

GRADING THE MATERIAL OF THE CURRICULUM

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After the essential material of the curriculum has been selected, the next important problem in curriculum construction is the gradation of this material. If one, for example, is working in the field of spelling, the problem is: How shall the words in the selected spelling list be assigned to the various grades? Selection of spelling words is made on the basis of frequency of usage, and since this in itself tells us nothing significant about grade location, it is evident that gradation presents an additional problem.

It may be well to state at the outset that little scientific work has been done on the gradation of material in any subject. In a very true sense it may be said that experts in curriculum making have not yet seriously attacked the problem. Their energies to date have been devoted almost exclusively to the many intricate problems involved in the selection of curriculum content. The selection problems naturally come first, but the time now seems ripe for a more critical investigation of grade allocation.

We may be pardoned, if, in the course of this discussion, we draw our illustrations rather liberally from the field of spelling, in the hope that the findings in spelling may have suggestive value for other subjects. It seems true that, in spite of the confusion and disagreement regarding the grading of words in spelling, the workers in this subject have made more progress with the problem than those in any other subject.

PRINCIPLES OF GRADING DEFINED

Although a number of different grading principles have been proposed for use in the field of spelling, there is as yet no general agreement as to which of these should be employed. We shall give consideration to four that have been used in the grading of word lists:

1. *Degree of difficulty for the child.*—The more difficult the word, the higher its place in the grades.

2. *Frequency of adult usage.*—The more frequently the word is used by adults, the lower it is placed in the grades.

3. *First usage of children.*—Grade placement is determined by the grade in which the word first appears in the writing of children.

4. *Frequency of usage in the writing of children.*—To a given grade those words are assigned which the children in that grade use most frequently in their written discourse.

It should be observed that each of these principles can be applied in a definite and objective manner. Quantitative data have been obtained for the application of the first principle by determining the percentage of misspelling on each word in the various grades. The best sources for such data are the Ayres-Buckingham Scale,[1] The Iowa Spelling Scales[2] and the Sixteen Spelling Scales.[3] In a spelling vocabulary of 3,818 words compiled by the writer, difficulty values for 2,995 of the words were found in the three sources mentioned.

As regards the second principle, very reliable frequency data are available on the words found in the correspondence of adults or, if one prefers to use not only the frequency of usage but also the range of usage, credit numbers representing both of these factors can be obtained.

Several investigations in the childhood field provide definite information in regard to the grade of first usage of words, and at least two studies show the frequency of words by grades. Thus we are in a position to begin the job of grading material in spelling by objective methods, if we can only decide upon the principle to be employed.

One finds himself in a peculiar position when asked to decide which principle or combination of principles is best for this purpose. The problem is one in the field of instructional methodology, where the authority for many principles still resides in the opinions of experts, and not in the results of scientific investigations. One is therefore compelled to study the workings and implications of the proposed principles as best he may, and select that principle or combination of principles that seems, from all the evidence at hand, to promise the most efficacious acquisition of spelling skill on the part of the child.

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[1] B. R. Buckingham, *Buckingham's Extension of the Ayres Spelling Scale.* Bloomington, Illinois: Public School Publishing Co.

[2] E. J. Ashbaugh, *The Iowa Spelling Scales: Their Derivation, Uses and Limitations.* Journal of Educational Research Monographs, No. 3. Bloomington, Illinois: Public School Publishing Co., 1922.

[3] Earl Hudelson, F. L. Stetson and Ella Woodyard, *Sixteen Spelling Scales Standardized in Sentences for Secondary Schools.* Teachers College Bulletin, Twelfth Series, No. 19. New York: Teachers College, Columbia University, 1921.

DISCUSSION OF PRINCIPLES USED IN GRADING

The four principles mentioned above seem by no means to be of equal value for grading purposes. If it is agreed that the basic principle in gradation is psychological, it should be observed that frequency of adult usage is not a psychological principle; it is sociological. When it is employed, as it has been in one of the prominent spelling courses on the market, the grade placement of material is determined not by conditions in the mind of the child, but by conditions in the life of the adult. Material most used by adults is introduced to the child at the earliest possible date in order, apparently, that its acquisition may be the more certain and secure. The mental maturity and interests of children are not considered. The theory represents a recrudescence of the pedagogy of force, and is distinctly reactionary in its trend. It is typical, however, of the practices of the extreme sociological school in education.

The difficulty principle has much more in its favor. In the gradation of subject matter it has generally made a strong appeal. This is largely on account of its psychological character; and there seems to be no question but that the grading of present school courses could be immensely improved if this principle were rigidly and accurately applied. It may even be said that much of the advancement in the conduct of the public schools has accrued from a better adjustment of tasks to the capacity of children to do them. There are considerations, however, that tend to make one skeptical in regard to the primacy of the difficulty principle in the field of spelling. There is the factor of interest, for example, which introduces complications that cannot be ignored. In other words, there is a conflict between two psychological principles—difficulty and interest. Where the two agree in the placement of a word, there is, of course, no problem. Where they disagree, which shall be regarded as the determining factor? To illustrate, take the relatively difficult words *Santa Claus, Christmas,* and *Thanksgiving Day.* Children are tremendously interested in these words and use them in writing as early as the second grade, but in a difficulty gradation the study of these words would be postponed to a much later period. On the other hand, consider the following simple three-letter words: *fee, tax, tan, due, art, bay, aid, dim, ill, gas, war, key, joy, wed, per.* Most of them are as easy to spell as *cat* and *pig,* but few children exhibit a desire to use them in their writing until the sixth, seventh and eighth grades.

Shall we be guided by interest or by difficulty in the grade allocation of these words? In the opinion of the writer, there is little doubt about the answer to this question. Ease of spelling is not a sufficient reason for teaching a word low in the grades, nor difficulty for teaching it at a higher level. Placing a word at that level of maturity where the pupils are interested in using it in their written expression seems to promise greater economy in learning and hence to reflect a sounder psychologic practice.

This brings us naturally to a discussion of the two remaining principles, each of which is founded on the interest motive. The question here is, which will distribute the words in the course more nearly in accord with the interests of the child—gradation according to first usage or gradation according to most frequent usage? The chief objection to the first of these principles is that it locates too many words in the early grades. Of the 3,000 words most frequently used by children in their writing, Tidyman found that 1,103 were used as early as the third grade. This principle would, therefore, lead to the assignment of many more words to the earlier grades than could possibly be taught there. Moreover, the use of a word by a single pupil in a grade is not a safe index of the readiness of the rest of the pupils in the grade for this word. It would seem much more sensible and sound to begin the gradation of the minimal list with the second grade, assigning to this grade the words most frequently used in the writing of second-grade pupils. The remainder of the list would then be canvassed for the words most frequently used in the writing of third-grade pupils, and by the same process the grading would proceed upward until all the words in the list had been located.

Data from H. J. Smith's study[4] may be used to make this method clearer. Smith tabulated 12,500 words from the spontaneous compositions of each grade from the third to the eighth, inclusive. For each word he shows the frequency of usage in each grade. For example, the tabulation for the word *egg* is as follows:

Word	Frequency by grades					
	VIII	VII	VI	V	IV	III
Egg	1	2	9	13	3	19

[4] H. J. Smith, "Spelling Vocabularies of Children in the Elementary School." Unpublished Study, Department of Education, University of Wisconsin, 1913.

Suppose, now, that one desires to select 300 of Smith's 2,046 words for teaching in the third grade. The last column to the right in his table will show all the words used by third graders. By the frequency-of-usage principle, one would select the 300 words in this column that have the highest frequency values.

GRADATION ACCORDING TO CHILDHOOD USAGE

The plan just described is what is meant by gradation in accordance with frequency of childhood usage. It can be illustrated in more detail by referring to the grading of 3,818 words in a recent publication.[5] From the investigation of children's themes made by H. J. Smith[6] and a study of children's letters made by W. C. French,[7] grading indices based on frequency of childhood usage were secured for many of the 3,818 words. From investigations by W. F. Jones[8] and W. F. Tidyman[9] two additional usage indices were derived. This was done by computing the relation between grade of first usage,[10] and grade of greatest frequency of usage as defined above. The Smith vocabulary was used for this purpose, since for each word it provides data concerning grade of first usage and, as indicated above, also enables one to determine the grade of most frequent usage. The 1,205 words for which the frequency data are most nearly adequate in this study were graded by the frequency-of-usage principle, then by the first usage principle, after which the results by the two methods were compared in detail.[11] The data indicate that the grading by the first principle places words on an average, approximately one grade higher than that by the second. The first-usage grading obtained from Jones' and Tidyman's studies was therefore increased by one grade to obtain an estimated usage grading.

When grading data were found for a word in all four of these investigations, the record appeared like that for the word *few*, reproduced below:

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[5] F. S. Breed and W. C. French, *The Breed-French Speller.* Chicago: Lyons and Carnahan, 1927.

[6] *Op. cit.*

[7] W. C. French, "A Study of Children's Letters." Unpublished Study, Department of Education, University of Chicago, 1925.

[8] W. Franklin Jones, *Concrete Investigation of the Material of English Spelling with Conclusions Bearing on the Problems of Teaching Spelling.* Vermilion, South Dakota: University of South Dakota, 1914.

[9] W. F. Tidyman, *Survey of the Writing Vocabularies of Public School Children in Connecticut.* Teacher's Leaflet No. 15. Washington: Bureau of Education, 1921.

[10] Jones assigned a word to "the lowest grade in which at least two per cent of the students used it." This was employed as the grade of first usage.

[11] C. B. Wood, "A Comparison of Two Methods of Grading Words." Unpublished Study, Department of Education, University of Chicago, 1925.

few

French, 3 Smith, 3
Jones, 3 Tidyman, 4

Grade Index, 3.3

The final grade position of the word was obtained by averaging the indices from the four investigations. When the data from these four investigations were inadequate for a word, supplementary data were sought in such studies as those made by Bauer[12] in New Orleans and Melcher[13] in Kansas City. When absolutely no childhood-usage data were available, as in the case of a limited number of words used by adults only, the general rule of assignment to the eighth grade was followed, on the theory that the pupils should be introduced to such words just before discontinuing the study of formal spelling.

DIFFERENT RESULTS FROM DIFFERENT METHODS

The reader may now be ready to ask whether or not there are significant differences in the gradation of the same words when different principles are employed. To throw some light on this question the data in Table IV are presented.

TABLE IV—PERCENTAGE OF AGREEMENT BETWEEN RESULTS OF DIFFERENT METHODS OF GRADING WORDS.

Grade	Difficulty of spelling and frequency of adult usage	Difficulty of spelling and frequency of childhood usage	Frequency of adult usage and frequency of childhood usage
2	56.3	78.0	57.7
3	25.2	26.5	20.2
4	19.6	23.0	.....
5	15.4	17.4	.....
6	16.1	18.8	.....
7	25.2	23.7	.....
8	32.9	11.1	4.6
Average	27.3	28.4	27.5

[12] Nicholas Bauer, *The Writing Vocabulary of Pupils in the New Orleans Public Schools.* New Orleans, Department of Superintendence, 1915.

[13] *Preliminary Report of the Committee on Spelling Appointed by the Elementary School Principals' Section.* Research Bulletin No. 2. Kansas City, Missouri: Public Schools, 1916.

The table shows the percentage of agreement in grading the same words when the principles mentioned above were applied as described below:

1. *Difficulty of spelling and frequency of adult usage.*—The 1,000 words in the Ayres Scale were graded, first according to the difficulty values of this scale, and secondly according to the frequency values in a compositive vocabulary of eleven investigations of adult correspondence.

2. *Difficulty of spelling and frequency of childhood usage.*—The difficulty values were taken from the Ayres Scale and the childhood-usage values from an unpublished study by the writer.

3. *Frequency of adult usage and frequency of childhood usage.*—The writer's childhood-usage gradation was compared with gradation according to the frequency values in the Andersen adult-correspondence list.

The table should be read as follows: Of the words assigned to grade 2 in accordance with the difficulty principle, 56.3 per cent were assigned to the same grade according to frequency of adult usage. It will be seen that the methods which have been compared agree in general more closely in the earlier grades than in the later ones, and that the average amount of agreement in the three comparisons is practically the same—about 28 per cent. This shows conclusively that very different results are obtained from these different principles of gradation. To some extent this difference is due, of course, to unreliability of the data employed, but inaccuracies from this source probably account for only a small part of this difference. This seems particularly true in regard to the results shown in the first column of the table. The difficulty values on the Ayres Scale and the frequency values in a composite of eleven investigations of adult correspondence are both quite reliable, yet the differences in gradation are highly marked.

COMPARISON OF DIFFICULTY AND ADULT-USAGE METHODS

One can secure a more detailed understanding of the relation between difficulty and adult-usage grading from Table V. The 1,000 words on the Ayres Scale were assigned to grades 2 to 8 according to difficulty, the 142 words of least difficulty being assigned to grade 2, and the remaining words in groups of 143 to successive grades according to increasing difficulty. The same words were then graded according to frequency of adult usage.

The frequency values in the composite of eleven investigations of adult correspondence were used. The number of words assigned to each grade was the same as before, the second grade receiving the 142 words of highest frequency, the third grade the 143 of next lower frequency, etc. The grading of each word by the one method was then compared with its grading by the other. Table V shows the results of this comparison. Grading by adult usage is indicated along the top of the table.

The second column of the table shows how the words assigned to the second grade according to adult usage, were distributed according to difficulty. Of the 142 words assigned to grade 2 by the usage principle, 80 were assigned to grade 2, 27 to grade 3, 15 to grade 4, and so on, by the difficulty principle. The most noticeable feature of the table, perhaps, is the difference between the gradings by the two methods, a fact which was indicated by the relatively low percentage of agreement noted in Table IV. In the bottom row of the table is presented the median difficulty grading for the words assigned to each of the grades on the basis of adult usage. By median difficulty grading is meant the position of the median in the difficulty scheme of gradation. For example, the words in the column for grade 8 have a median position of 7 on the difficulty scale. In no case does the general trend of the difficulty grading vary from the adult-usage grading by more than one grade. Similar medians for adult-usage grading are presented in the column farthest to the right, for comparison with the difficulty grading. Here also, a difference no greater than one grade is indicated. One should not, however, permit this use of median values to distort his interpretation. It might be better to dismiss the medians as aids to interpretation, for it is probably of more significance to note that, without exception, the words placed in any grade by one method are distributed over all the grades by the other method.

Difficulty and Childhood Usage Compared

In Table VI is presented a comparison of difficulty gradation with gradation on the basis of childhood usage. The 1,000 Ayres-Scale words were graded according to difficulty. Then the difficulty grading of each of these words was compared with its childhood-usage grading in a list of 3,818 words. Here again the median gradation by one method nowhere differs from the median

TABLE V—COMPARISON OF THE GRADATION OF THE 1,000 AYRES-SCALE WORDS BY DIFFICULTY OF SPELLING AND BY FREQUENCY OF ADULT USAGE.

Gradation by difficulty of spelling	Graduation by frequency of adult usage							Total	Median usage grading
	2	3	4	5	6	7	8		
2	80	22	14	11	8	3	4	142	2
3	27	36	27	20	14	16	3	143	4
4	15	34	28	23	26	12	5	143	4
5	10	21	26	22	23	21	20	143	5
6	6	14	23	25	23	22	30	143	6
7	3	8	15	19	28	36	34	143	6
8	1	8	10	23	21	23	47	143	7
Total	142	143	143	143	143	143	143	1,000	
Median difficulty grading	2	4	5	5	6	6	7		

gradation by the other by more than one grade. On the whole, the results indicate that the 1,000 words tend to take a lower place in the grades when the interest principle is applied than when the difficulty principle is applied. This conclusion is suggested by the tendency of the words to cluster on the left side of the table, and also by the increasing totals of the columns from right to left. Before, however, one can conclude for a certainty that the gradation in the one case is lower than that in the other, an additional factor must be taken into consideration.

In the comparison of gradings by these two methods, there is the tacit assumption that the words on the Ayres Scale constitute a satisfactory sample of the whole range of difficulty of the minimal spelling list. This assumption is implied in the uniform distribution of the 1,000 words over the whole grade range, and is probably not valid. For example, the 1,000 commonest words are certainly of lower average difficulty than the remaining words in the minimal list. If this be conceded, the true difficulty grading of the words would be lower than that presented in Table VI. This lower grading would lessen the difference between the two types of grading exhibited, for the childhood-usage grading shown in the table represents the grade allocation of these 1,000 words when they are considered along with the rest of the minimal list. This assumption, it may be explained, does not enter as a factor in the

TABLE VI—COMPARISON OF THE GRADATION OF THE 1,000 AYRES-SCALE WORDS BY DIFFICULTY OF SPELLING AND BY FREQUENCY OF CHILDHOOD USAGE.

Gradation by difficulty of spelling	Gradation by frequency of childhood usage							Words not in both lists	Total	Median usage grading
	2	3	4	5	6	7	8			
2	111	19	9	1	1	0	0	1	142	2
3	52	38	25	10	2	0	0	16	143	3
4	35	40	33	18	6	1	0	10	143	3
5	19	30	33	25	20	6	2	8	143	4
6	8	29	24	21	27	24	0	10	143	5
7	2	8	14	27	35	34	5	18	143	6
8	3	8	5	11	29	47	16	24	143	7
Total	230	172	143	113	120	112	23	87	1,000	
Median difficulty grading	3	4	5	6	7	7	8			

interpretation of Table V, because in that case the same 1,000 words were graded by each method as if they constituted the entire spelling vocabulary.

In order to test the above assumption,[14] a comparison was made between the difficulty and childhood-usage gradings of the same 3,818 words. The difficulty grading was made on the basis of objectively determined difficulty values, the least difficult words being assigned to the second grade, those next in difficulty to the third grade, and so on. The number of words assigned to each grade was the same in the two gradings. The childhood-usage grading was that of the writer, previously referred to.

The results of this comparison are shown in Table VII. It is evident from this table that words do not receive a lower gradation by the childhood-usage method. This is best seen in the columns entitled "Median Usage Grading" in Tables VI and VII. Whereas in Table VI the usage gradation was found to average lower than the other in five of the seven grades, in Table VII the usage grading is found to be higher in one grade, lower in two, and the same in the remaining four. It is fairly evident that one organization of the words is neither more nor less difficult than the other. An excess of difficulty in one grade is balanced by the opposite condition in another.

[14] For assistance in making this comparison the writer is indebted to Olive McFadden and Ethel A. Elder.

TABLE VII—COMPARISON OF THE GRADATION OF 3,818 WORDS BY DIFFICULTY OF SPELLING AND BY FREQUENCY OF CHILDHOOD USAGE.

Gradation by difficulty of spelling	Graduation by frequency of childhood usage							Total	Median usage grading	Percentage of agreement
	2	3	4	5	6	7	8			
2	207	101	36	16	2	0	0	362	2	57.2
3	77	153	182	122	35	7	0	576	4	26.6
4	50	153	168	167	74	28	8	648	4	25.9
5	23	95	144	135	135	76	40	648	5	20.8
6	3	36	59	84	150	137	107	576	6	26.0
7	2	34	43	77	103	114	131	504	6	22.6
8	0	4	16	47	77	142	218	504	7	43.3
Total	362	576	648	648	576	504	504	3,818		Average 31.8
Median dificulty grading	2	4	4	5	6	7	7			

It is well to notice that the two methods of grade placement just described give identical positions to 31.8 per cent of the words, a higher percentage than has been found in any of the other comparisons.

CONCLUSIONS

It seems evident that a solution of the problem of grading curriculum materials requires (1) the establishment of the principle or principles to be applied and (2) the determination of methods for applying these principles. Although intelligent discussions will no doubt aid in the selection of principles, specific investigations of the effects of various principles and methods of applying them will be necessary before satisfactory conclusions can be reached.

Fortunately, in the case of each of the principles treated in the foregoing discussion, objective data for their application have been secured. These data, however, are not in every instance as extensive as they should be. This is especially true, for example, in regard to the data available for the application of the childhood-usage principle, and is due to the failure of many investigators to supply frequency of word usage by grades. Grading words by this method will be materially improved when more adequate data of this kind are provided.

A point has been reached in the study of word gradation where the advantages and disadvantages of several conflicting principles stand out in bolder relief. It is apparent that these principles differ greatly in the theoretic support which they can command and in the results which they produce. Frequency of adult usage has least to recommend it. Grade of first usage in unpractical and unpsychological—unpractical because of the congestion of words occasioned in the lower grades, unpsychological because it represents a standard of precocity and not of normalcy. Difficulty of spelling and frequency of usage among children are apparently the most satisfactory bases, and, of these, the second seems to be the better. That is, it seems most psychological to teach a child, in a given grade, to spell the words which he most commonly uses in his writing in that grade.

The degree to which results differ when different principles are applied in grading the same words is indicated by the small percentages representing the number of words identically located. These percentages vary from 27.3 to 31.8. Difference in results is also indicated by the fact that words located in a given grade by one method are often distributed over all the grades by another method.

CONSTITUTION AND BY-LAWS
AND
LIST OF MEMBERS

CONSTITUTION AND BY-LAWS

OF THE

ILLINOIS STATE ACADEMY OF SCIENCE

CONSTITUTION.

ARTICLE I. NAME.

This Society shall be known as THE ILLINOIS STATE ACADEMY OF SCIENCE.

ARTICLE 11. OBJECTS.

The objects of the Academy shall be the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the science interests of the State.

ARTICLE 111. MEMBERS.

The membership of the Academy shall consist of two classes as follows: *National Members and Local Members.*

National Members shall be those who are members also of the American Association for the Advancement of Science.

Local Members shall be those who are members of the local Academy only. Each member, except life members of the Academy, shall pay an admission fee of one dollar and an annual assessment of one dollar.

Both national members and local members may be either *Life Members, Active Members, or Non-resident Members.*

Life Members shall be national or local members who have paid fees to the Academy to the amount of twenty dollars at one time or complete payments before the annual meeting of 1928. The dues from such a source are to be placed as a permanent fund and only the income is to be used.

Active Members shall be national or local members who reside in the State of Illinois.

Non-resident Members shall be active members or life members who have removed from the State of Illinois. Their duties and privileges shall be the same as active members except that they may not hold office.

Charter Members are those who attended the organization meeting in 1908, signed the constitution, and paid dues for that year.

For election to any class of membership, the candidate's name must be proposed by two members, be approved by a majority of the committee on membership, and receive the assent of three-fourths of the members voting.

ARTICLE IV. OFFICERS.

The officers of the Academy shall consist of a President, a First Vice-President, a Librarian, a Secretary, and a Treasurer. The Chief of the Division of State Museum of the Department of Registration

and Education of the State Government shall be the Librarian of the Academy. These officers, except the Librarian, shall be chosen by ballot on recommendation of a nominating committee, at an annual meeting, and shall hold office for one year or until their successors qualify.

A Second Vice-President, who may be a resident of the town in which the next annual meeting is to be held, may be appointed by the council each year when the next meeting place shall have been decided upon.

The above officers shall perform the duties usually pertaining to their respective offices.

It shall be one of the duties of the President to prepare an address which shall be delivered before the Academy at the annual meeting at which his term of office expires.

The Librarian shall have charge of all the books, collections, and material property belonging to the Academy.

ARTICLE V. COUNCIL.

The Council shall consist of the President, First Vice-President, Second Vice-President, Secretary, Treasurer, Librarian, the retiring president and his immediate predecessor. To the Council shall be entrusted the management of the affairs of the Academy during the intervals between regular meetings.

At the Annual Meetings the presiding officer of each of the affiliated scientific societies of the State shall meet with the Academy Council for the discussion of policies.

ARTICLE VI. STANDING COMMITTEES.

The Standing Committees of the Academy shall be a Committee on Publication, a Committee on Membership and a Committee on Affiliation and such other committees as the Academy shall from time to time deem desirable.

The Committee on Publication shall consist of the President, the Secretary and a third member chosen annually by the Academy.

The committees on Membership and affiliation shall each consist of five members chosen annually by the Academy.

ARTILCE VII. MEETINGS.

The regular meetings of the Academy shall be held at such time and place as the Council may designate. Special meetings may be called by the Council, and shall be called upon written request of twenty members.

ARTICLE VIII. PUBLICATIONS.

The regular publications of the Academy shall include the Transactions of the Academy and such papers as are deemed suitable by the Committee on Publications.

All members shall receive gratis the current publication of the Academy.

ARTICLE IX. AFFILIATION.

The Academy may enter into such relations of affiliation with other organizations of appropriate character as may be recommended by the Council, and may be ordered by a three-fourths vote of the members present at any regular meeting.

ARTICLE X. AMENDMENTS.

This constitution may be amended by a three-fourths vote of the membership present at an annual meeting, provided that notice of the desired change has been sent by the Secretary to all members at least twenty days before such meeting.

BY-LAWS.

I. The following shall be the regular order of business:

1. Call to order.
2. Reports of officers.
3. Reports of standing committees.
4. Election of members.
5. Reports of special committees.
6. Appointment of special committees.
7. Unfinished business.
8. New business.
9. Election of officers.
10. Program.

Adjournment.

II. No meeting of the Academy shall be held without thirty days previous notice by the Secretary to all members.

III. Fifteen members shall constitute a quorum of the Academy. A majority of the Council shall constitute a quorum of the Council.

IV. No bill against the Academy shall be paid without an order signed by the President and the Secretary.

V. Members who shall allow their dues to remain unpaid for three years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

VI. The Librarian shall have charge of the distribution, sale, and exchange of the published Transactions of the Academy, under such restrictions as may be imposed by the Council.

VII. The presiding officer shall at each annual meeting appoint a committee of three who shall examine and report in writing upon the account of the Treasurer.

VIII. No paper shall be entitled to a place on the program unless the manuscript or an abstract of the same shall have been previously delivered to the Secretary. No paper shall be presented at any meeting, by any person other than the author, except on vote of the members present at such meeting. No paper shall be published unless the manuscript be handed to the Secretary within thirty days after the Annual meeting. All papers are limited to twenty pages, additional pages are to be paid for by the author. Except by invitation of the Council, no paper may be accepted for the program unless the author is a member of the Academy or an applicant for membership.

IX. The Secretary and the Treasurer shall have their expenses paid from the Treasury of the Academy while attending council meetings and annual meetings. Other members of the council may have their expenses paid while attending meetings of the council, other than those in connection with annual meetings.

X. These by-laws may be suspended by a three-fourths vote of the membership present at any regular meeting.

ILLINOIS STATE ACADEMY OF SCIENCE

LIST OF MEMBERS.

(January 1, 1930)

Note—The names of charter members are starred; names in black-faced type indicate membership in the American Association for the Advancement of Science. Numerals in parenthesis after each member indicate the date of joining the Academy.

LIFE MEMBERS.

Allee, W. C., Ph. D., University of Chicago, Chicago, Ill. (Zoology.) (1913.)
*Andrews, C. W., LL. D., The John Crerar Library, Chicago, Ill. (Scientific Bibliography.) (1908.)
*Atwell, Chas. B., M. Ph., 545 Post St., San Francisco, Cal. (Botany.) (1908.)
*Bain, Walter G., M. D., St. John's Hospital, Springfield, Ill. (Bacteriology.) (1908.)
*Baker, Frank C., University of Illinois, Urbana, Ill. (Zoology.) (1908.)
*Barnes, R. M., LL.B., Lacon, Ill. (Zoology.) (1908.)
*Barnes, William, M. D., 320 Millikin Bldg., Decatur, Ill. (Lepidoptera.) (1908.)
*Bartow, Edward, Ph. D., Univ. of Iowa, Iowa City, Iowa. (Chemistry.) (1908.)
*Barwell, John Wm., Madison and Sand Sts., Waukegan, Ill. (Anthropology.) (1908.)
*Bayley, W. S., Ph. D., University of Illinois, Urbana, Ill. (Geology.) (1908.)
*Betten, Cornelius, Ph. D., Cornell University, Ithaca, N. Y. (Biology.) (1908.)
Blair, Mary Constance, Ph. D., 1011 Grove St., Evanston, Ill. (Botany, Zoology.) (1926.)
*Bleininger, A. V., B. S., Homer Laughlin China Co., Newell, W. Va. (Ceramics.) (1908.)
Bliss, Gilbert Ames, Ph. D., 5625 Kenwood Ave., Chicago, Ill. (Mathematics.) (1926.)
*Carman, Albert P., Ph. D., University of Illinois, Urbana, Ill. (Physics.) (1908.)
*Carpenter, Chas. K., D. D., Baileyville, Ill. (Ornithology.) (1908.)
Chamberlain, C. J., Ph. D., University of Chicago, Chicago, Ill. (Botany.) (1911.)
Child, C. M., Ph. D., University of Chicago, Chicago, Ill. (Zoology.) (1910.)
*Clawson, A. B., B. A., Dept. of Agriculture, Washington, D. C. (Biology.) (1908.)
*Cowles, H. C., Ph. D., University of Chicago, Chicago, Ill. (Botany.) (1908.)
*Crew, Henry, Ph. D., Northwestern University, Evanston, Ill. (Physics.) (1908.)
*Crook, A. R., Ph. D., Chief, State Museum, Springfield, Ill. (Geology.) (1908.)
*Davis, J. J., B. S., Purdue University, Lafayette, Ind. (Entomology.) (1908.)
*Deal, Don. W., M. D., Leland Office Bldg., Springfield, Ill. (Medicine.) (1908.)
Ekblaw, George Elbert, Ph. D., 308 Lincoln, Urbana, Ill. (Geology.) (1924.)
*Ekblaw, W. E., Ph. D., Clark University, Worcester, Mass. (Geology.) (1908.)
*Ewing, H. E., Ph. D., U. S. Nat. Museum, Washington, D. C. (Biology.) (1908.)
*Farrington, O. C., Ph. D., Field Museum, Chicago, Ill. (Mineralogy.) (1908.)
*Fischer, C. E. M., M. D., 25 E. Washington St., Chicago, Ill. (Medicine.) (1908.)
*Fisher, Fannie, Ass't Curator, State Museum, Springfield, Ill. (General Interest.) (1908.)
*Forbes, S. A., LL. D., Chief, Natural History Survey, Urbana, Ill. (Zoology.) (1908.)
Fuller, Geo. D., Ph. D., University of Chicago, Chicago, Ill. (Botany.) (1912.)

*Gates, Frank C., Ph. D., State Agricultural Coll., Manhattan, Kan. (Botany.) (1908.)
*Gerhard, Wm. J., M. A., Field Museum, Chicago, Ill. (Zoology.) (1908.)
*Grant, U. S., Ph. D., Northwestern University, Evanston, Ill. (Geology.) (1908.)
*Gurley, Wm. F. E., 6151 University Ave., Chicago, Ill. (Paleontology.) (1908.)
Hagler, E. E., M. D., Capitol Ave. and Fourth St., Springfield, Ill. (Oculist.) (1910.)
*Hale, John A., M. D., 117½ W. Ninth St., Los Angeles, Calif. (Medicine.) (1908.)
*Hankinson, Thos. L., B. S., State Normal College, Ypsilanti, Mich. (Zoology). (1908.)
*Hawthorne, W. C., M. S., Crane Junior College, Chicago, Ill. (Physics.) (1908.)
*Hessler, J. C., Ph. D., Knox College, Galesburg, Ill. (Chemistry.) (1908.)
*Holgate, T. F., Ph. D., LL. D., 617 Library St., Evanston, Ill. (Mathematics.) (1908.)
*Hoskins, William, 49 Sixth Ave., La Grange, Ill. (Chemistry.) (1908.)
*Hottes, C. F., Ph. D., University of Illinois, Urbana, Ill. (Botany.) (1908.)
Hudelson, C. W., M. S., 206 S. Main St., Normal, Ill. (Agriculture.) (1921.)
*Hunt, Robt. I., Decatur, Ill. (Soils.) (1908.)
*Hutton, J. Gladden, M. S., State College, Brookings, S. D. (Agronomy.) (1908.)
Jordan, Edwin O., Ph. D., University of Chicago, Chicago, Ill. (Bacteriology.) (1912.)
*Kneale, Elmer J., Illinois State Register, Springfield, Ill. (Astronomy.) (1908.)
*Knipp, Charles T., Ph. D., University of Illinois, Urbana, Ill. (Physics.) (1908.)
Kuntz, Jacob, Ph. D., University of Illinois, Urbana, Ill. (Physics.) (1919.)
*Langford, George, B. S., McKenna Process Co., Joliet, Ill. (Paleontology.) (1908.)
Latham, Vida A., M. D., D. D. S., 1644 Morse Ave., Chicago, Ill. (Microscopy.) (1909.)
Lillie, F. R., Ph. D., University of Chicago, Chicago, Ill. (Zoology.) (1912.)
Marshall, Ruth, Ph. D., Rockford College, Rockford, Ill. (Zoology.) (1912.)
McDougall, W. B., Ph. D., 201 S. Busey St., Urbana, Ill. (Botany.) (1916.)
*Michelson, A. A., Ph. D., Sc. D., LL. D., University of Chicago, Chicago, Ill. (Physics.) (1908.)
Miller, G. A., Ph. D., University of Illinois, Urbana, Ill. (Mathematics.) (1910.)
Moffatt, Mrs. Elizabeth M., 1315 Crown Hill Ave., Los Angeles, Calif. (Zoology.) (1916.)
Moffatt, Will S., M. D., 1315 Crown Hill Ave., Los Angeles, Calif. (Botany.) (1912.)
Mohr, Louis, 349 W. Illinois St., Chicago, Ill. (General Interest.) (1909.)
*Noyes, Wm. A., Ph. D., LL. D., University of Illinois, Urbana, Ill. (Chemistry.) (1908.)
*Oglevee, C. S., Sc. D., Lincoln College, Lincoln, Ill. (Biology.) (1908.)
O'Hara, Fred S., M. D., 509 E. N. Grand Ave., Springfield, Ill. (Medicine.) (1925.)
*Parr, S. W., Sc. D., University of Illinois, Urbana, Ill. (Chemistry.) (1908.)
Payne, Edward W., First State Trust & Savings Bank, Springfield, Ill. (Archeology.) (1909.)
*Pepoon, H. S., M. D., Lake View High School, Chicago, Ill. (Zoology, Botany.) (1908.)
Reagan, Albert B., Ph. D., U. S. Indian Field Service, Ouray, Utah. (Paleontology.) (1921.)
Rentchler, Edna K., B. A., Peabody Normal College, Nashville, Tenn. (Biology.) (1912.)
*Savage, T. E., Ph. D., University of Illinois, Urbana, Ill. (Strategraphic Geology.) (1908.)
Schaffer, David Nicholas, M. D., 603 Main St., Evanston, Ill. (Medicine.) (1925.)
*Shelford, V. E., Ph. D., Vivarium Bldg., Wright and Healy Sts., Champaign, Ill. (Zoology, Ecology.) (1908.)
*Slocum, A. W., 5549 Dorchester Ave., Chicago, Ill. (Paleontology.) (1908.)
*Smallwood, Mabel E., 550 Surf St., Chicago, Ill. (Zoology.) (1908.)
Smith, Mrs. Eleanor C., B. S., 104 Winston Ave., Joliet, Ill. (Biology.) (1919.)
Smith, Frank, Sc. D., 79 Fayette St., Hillsdale, Mich. (Zoology.) (1909.)
*Smith, Isabel Seymour, Ph. D., 145 Woodland Ave., Oberlin, Ohio. (Botany.) (1908.)
*Smith, Jesse L., Supt. of Schools, Highland Park, Ill. (Botany.) (1908.)
*Smith, L. H., Ph. D., University of Illinois, Urbana, Ill. (Plant Breeding.) (1908.)
*Spicer, C. E., 100 Sherman St., Joliet, Ill. (Chemistry.) 1908.)
*Stevenson, A. L., B. S., Field School, 7019 N. Ashland Ave., Chicago, Ill. (Science.) (1908.)
*Stillhamer, A. G., 705 N. East St., Bloomington, Ill. (Physics.) (1908.)
*Strode, W. S., M. D., Lynwood, Calif. (Ornithology.) (1908.)

*Sykes, Mabel, B. S., South Chicago High School, Chicago, Ill. (General Interest.) (1908.)
Trelease, William, Sc. D., LL. D., University of Illinois, Urbana, Ill. (Botany.) (1909.)
*Turton, Chas. M., M. A., 2055 E. 72nd Place, Chicago, Ill. (Physics.) (1908.)
Van Cleave, H. J., Ph. D., University of Illinois, Urbana, Ill. (Zoology.) (1910.)
Ward, Henry B., Ph. D., Sc. D., University of Illinois, Urbana, Ill. (Zoology.) (1910.)
Washburn, E. W., Ph. D., Bureau of Standards, Washington, D. C. (Chemistry.) (1910.)
*Weller, Annie L., B. S., Eastern Ill. State Teachers' College, Charleston, Ill. (Geography.) (1908.)
*Winter, S. G., M. A., Lombard College, Galesburg, Ill. (Histology.) (1908.)
Zeleny, Charles, Ph. D., University of Illinois, Urbana, Ill. (Experimental Zoology.) (1910.)
*Zetek, James, M. A., Box 245, Ancon, Panama Canal Zone. (Entomology.) (1908.)

ANNUAL MEMBERS.

Adams, H. W., B. S., Normal University, Normal, Ill. (Chemistry.) (1928.)
Adams, L. A., Ph. D., University of Illinois, Urbana, Ill. (Zoology.) (1923.)
Adams, Roger, Ph. D., University of Illinois, Urbana, Illinois. (Chemistry.) (1926.)
Adams, William A., B. S., 2235 N. 75th Ave., Elmwood Park, Ill. (Archeology.) (1927.)
Adamstone, F. B., Ph. D., University of Illinois, Urbana, Illinois. (Zoology.) (1926.)
Adler, Herman M., M. D., 119 E. Huron St., Chicago, Ill. (Medicine.) (1920.)
Agersborg, H. P. K., Ph. D., Shepherdstown, W. Va. (Zoology.) (1925.)
Aldrich, Frank W., Ph. D., 1506 E. Washington St., Bloomington, Ill. (Anthropology.) (1925.)
Alexander, Alida, M. A., Illinois Woman's College, Jacksonville, Ill. (Botany.) (1918.)
Ames, E. S., Ph. D., University of Chicago, Chicago, Ill. (Psychology.) (1920.)
Anderson, Martha, M. D., Hillcrest Sanitarium, Quincy, Ill. (Pathology.) (1928.)
Appleton, John B., Ph. D., Scripps College, Claremont, California. (Geography.) (1926.)
Armstrong, Christie, B. A., Princeville, Ill. (Geography.) (1921.)
Arn, William G., B. S., Illinois Central Station, I. C. R. R. Co., Chicago, Ill. (Mathematics, Geology, Physics.) (1927.)
Ashman, George C., Ph. D., Bradley Institute, Peoria, Ill. (Chemistry.) (1913.)
Astell, Louis A., B. A., Box 37, West Chicago, Ill. (Physiology and Hygiene.) (1925.)
Audrieth, Ludwig E., 1210 W. California, Urbana, Ill. (Chemistry.) (1929.)
Augur, Allison W., M. A., Tilden Technical High School, Chicago, Ill. (Physics). (1921.)
Bacon, Chas. Sumner, Ph. D., M. D., 2333 Cleveland Ave., Chicago, Ill. (Medicine.) (1920.)
Bacon, Joseph B., M. D., Macomb, Ill. (Surgery.) (1929.)
Badger, C. J., B. S., Ewing, Ill. (Soils.) (1929.)
Bailey, Mrs. Alice Allen, M. S., University of Chicago, Chicago, Ill. (Botany, Pathology, 1927.)
Bailey, Wm. M., M. S., 701 S. Poplar, Carbondale, Ill. (Botany.) (1921.)
Baker, C. J., B. S., 406 E. Ohio St., Chicago, Ill. (Chemistry.) (1926.)
Balduf, W. V., Ph. D., 208 Old Law Bldg., University of Illinois, Urbana, Ill. (Entomology.) (1924.)
Ball, John R., Ph. D., Northwestern University. (Geology.) (1929.)
Banck, Hans J. E., M. E., 1422 Dial Court, Springfield, Ill. (Engineering.) (1925.)
Bangs, Edward H., 168 Addison Road, Riverside, Ill. (Agriculture, Electricity.) (1920.)
Barnes, Cecil, M. A., 1514 1st National Bank Bldg., Chicago, Ill. (Physical Geography.) (1920.)
Bartlett, R. W., 810 W. Nevada St., Urbana, Ill. (Economics.) (1929.)
Bassett, C. F., M. A., Apartado 172, Maracaibo, Venezuela, S. A. (Geology.) (1925.)
Bassett, Mrs. C. F., B. S., Apartado 172, Maracaibo, Venezuela, S. A. (Geology.) (1926.)
Bastin, E. S., Ph. D., University of Chicago, Chicago, Ill. (Geology.) (1925.)
Bates, Onward, D. Eng., LL. D., 934 John's Rd., Augusta, Ga. (Civil Engineering.) (1926.)
Beecher, Wm. L., M. D., Ph. D., 4607 Beacon St., Chicago, Ill. (Medicine.) (1927.)
Behre, Chas. H., Jr., Ph. D., University of Cincinnati, Cincinnati, Ohio. (Geology.) (1921.)
Bell, Alfred H., Ph. D., University of Illinois, Urbana, Ill. (Geology.) (1927.)
Bell, Marie, Box 114, Albany, Ind. (Biology.) (1926.)

Bengel, George A., 808 S. 4th St., Springfield, Ill. (Engineering.) (1925.)
Bennett, Mary A., 623 E. Carroll St., Macomb, Ill. (Zoology.) (1929.)
Bentley, Madison, Ph. D., Department of Psychology, Cornell Univ., Ithaca, N. Y. (Psychology.) (1920.)
Benton, Curtis, M. S., Bur. Entomology, U. S. Dep't. of Agriculture, Lafayette, Ind. (Entomology.) (1925.)
Bergeim, Olaf, Ph. D., 1017 W. Polk St., Chicago, Ill. (Chemistry.) (1928.)
Bergman, Ross M., 613 S. Hale St., Wheaton, Ill. (Biology.) (1926.)
Bergsmark, Daniel R., B. S., University of Cincinnati, Cincinnati, Ohio. (Geography.) (1928.)
Bevan, Arthur, Ph. D., State Geologist, Charlottesville, Va. (Geology.) (1928.)
Bigger, J. H., B. S., 1114 S. Main St., Jacksonville, Ill. (Entomologist.) (1925.)
Bishop, Samuel W., 326½ W. Adams St., Macomb, Ill. (Biology.) (1929.)
Black, Arthur D., M. D., D. D. S., Northwestern University, Evanston, Ill. (Dentistry.) (1921.)
Blackstock, Ira B., M. A., 213 E. Jefferson St., Springfield, Ill. (Agriculture.) (1925.)
Blake, Anna M., B. S., 409 W. Willow St., Normal, Ill. (Botany, Physiology.) (1917.)
Blake, Mrs. Tiffany, Lake Forest, Ill. (General Interest.) (1921.)
Blanchard, W. O., Ph. D., 305 Washington Blvd., Urbana, Ill. (Geography.) (1925.)
Block, D. Julian, Ph. D., 612 N. Michigan Blvd., Chicago, Ill. (Chemistry.) (1920.)
Boewe, G. H., B. Ed., 313 Taylor St., Charleston, Ill. (General Interest.) (1928.)
Bogusch, Edwin R., M. A., University of Illinois, Urbana, Ill. (Botany.) (1929.)
Bohannon, F. C., B. S., Galesburg High School, Galesburg, Ill. (Geography, Geology.) (1924.)
Bonnell, Clarence, Township High School, Harrisburg, Ill. (Biology.) (1926.)
Boomer, S. E., M. A., 207 Harwood St., Carbondale, Ill. (Physics.) (1921.)
Boos, Mrs. Margaret Fuller, Ph. D., 818 E. Seneca Ave., McAlister, Okla. (Geology.) (1920.)
Boot, G. W., M. D., 813 Sherman Ave., Evanston, Ill. (Medicine, Geology.) (1920.)
Brandenburger, F., B. Ed., Milstadt, Ill. (Geology.) (1928.)
Breed, Frederick S., Ph. D., School of Education, Univ. of Chicago, Chicago, Ill. (Education.) (1921.)
Bregowsky, Ivan M., 4600 W. Harrison St., Chicago, Ill. (Chemistry, Metallurgy.) (1926.)
Bretz, J. Harlan, Ph. D., University of Chicago, Chicago, Ill. (Geology.) (1921.)
Brink, William G., Ph. D., Northwestern University, Evanston, Ill. (Psychology.) (1929.)
Brown, Agnes, B. A., 1205 W. State St., Rockford, Ill. (Botany.) (1921.)
Brown, George A., 304 E. Walnut St., Bloomington, Ill. (Education.) (1920.)
Browne, G. Aritins, B. S., Community High School, Lincoln, Ill. (Physics.) (1928.)
Browne, George M., 902 S. Normal St., Carbondale, Ill. (Chemistry.) (1921.)
Brundage, John T., M. A., St. Louis University School of Medicine, 1403 Grand Ave., St. Louis, Mo. (Physiological Chemistry.) (1927.)
Bussart, J. Everett, B. S., Wheaton High School, Wheaton, Ill. (Biology.) (1928.)
Buswell, A. M., Ph. D., Chief, State Water Survey, University of Illinois, Urbana, Ill. (Sanitary Chemistry.) (1921.)
Buzzard, Robt. G., M. S., 608 Normal Ave., Normal, Ill. (Geography, Geology.) (1922.)
Cady, Gilbert H., Ph. D., 504 W. Oregon St., Urbana, Ill. (Geology.) (1924.)
Cahn, Alvin R., Ph. D., University of Illinois, Urbana, Ill. (Zoology.) (1925.)
Caldwell, Delia, M. D., 590 W. Main St., Carbondale, Ill. (Medicine.) (1921.)
Cammach, R. R., B. S., 409 S. Buchannan St., Marion, Ill. (Chemistry.) (1926.)
Campbell, Ian, M. A., Geological Museum, Cambridge, Mass. (Geology.) (1925.)
Cantwell, Thomas, Crane Junior College, Chicago, Ill. (Zoology.) (1929.)
Card, H. H., M. A., Washington University, St. Louis, Mo. (Botany.) (1925.)
Carleton, Ralph Kimball, M. A., Shurtleff College, Alton, Ill. (Chemistry.) (1926.)
Carlson, A. J., Ph. D., University of Chicago, Chicago, Ill. (Physiology.) (1911.)
Carlson, Fred, B. Ed., 5556 University Ave., Chicago, Ill. (Geography.) (1923.)
Carrick, O. W., B. S., 543 S. Cuyler Ave., Oak Park, Ill. (Chemistry.) (1928.)
Causey, David, Ph. D., University of Arkansas, Fayetteville, Ark. (Biology.) (1922.)
Caven, Jordon, M. A., Rockford College, Rockford, Ill. (Psychology.) (1926.)
Cavins, Harold M., B. S., Charleston, Ill. (Agriculture.) (1929.)
Challis, Frank E., B. S., 121 N. Wabash Ave., Chicago, Ill. (Chemistry.) (1921.)

Chandler, S. C., B. S., Carbondale, Ill. (Entomology.) (1921.)
Chapman, Hazel, B. A., 301 W. Washington St., Urbana, Ill. (Zoology.) (1925.)
Cheddix, J. C., B. Ed., 312 Water St., Normal, Ill. (Chemistry.) (1928.)
Chester, S. Arthur, B. S., 802 Normal Ave., Normal, Ill. (Physics.) (1928.)
Christie, J. R., M. S., East Falls Church, Va. (Biology.) (1929.)
Clark, Albert Henry, B. S., 701 W. Wood St., Chicago, Ill. (Chemistry.) (1920.)
Clark H. Walton, M. A., California Academy of Sciences. Golden Gate Park, San Francisco, Calif. (Biology.) (1917.)
Clark, John, 552 Kenilworth Ave., Glen Ellyn, Ill. (Paleontology.) (1929.)
Clement, J. A., 309 Administration Bldg., University of Illinois, Urbana, Ill. (Biology.) (1929.)
Cletcher, J. O., M. D., 10 N. Main St., Tuscola, Ill. (Medicine.) (1921.)
Clute, W. N., B. A., Butler University, Indianapolis, Ind. (Botany.) (1918.)
Coale, Henry K., Highland Park, Illinois. (Ornithology.) (1926.)
Coffin, Fletcher B., Ph. D., Lake Forest, Ill. (Physical Chemistry.) (1911.
Coggeshall, Ruth, B. S., 3927 N. Hamlin Ave., Chicago, Ill. (Biology.) (1924.)
Colby, Arthur Samuel, Ph. D., University of Illinois, Urbana, Ill. (Horticulture.) (1920.)
Colby, Chas. C., Ph. D., University of Chicago, Chicago, Ill. (Geography.) (1920.)
Cole, Fay-Cooper, Ph. D., 5710 Blackstone, Chicago, Ill. (Anthropology.) (1927.)
Colyer, F. H., M. S., Southern Illinois State Teachers' College, Carbondale, Ill. (Geography.) (1915.)
Compton, James S., Eureka, Ill. (General Interest.) (1914.)
Cooper, Rachel M., M. D., State Normal University, Normal, Ill. (Medicine.) (1928.)
Crandle, Ellis R., B. Ed., 509 S. Poplar, Carbondale, Ill. (Biology.) (1927.)
Crathorne, A. R., Ph. D., University of Illinois, Urbana, Ill. (Mathematics.) (1920.)
Cribb, Aubrey, "The Associated Press," Springfield, Ill. (General Interest.) (1921.)
Crompton, Mabel, M. S., 310 Normal Ave., Normal, Ill. (Geography.) (1927.)
Crosier, W. M., M. D., Alexis, Ill. (Medicine.) (1921.)
Cross, C. L., M. S., 604 Normal Ave., Normal, Ill. (Physics.) (1928.)
Crowe, A. B., M. A., Eastern State Teachers' College, Charleston, Ill. (Physics.) (1910.)
Croxton, Orson, B. S., 128 W. Hickory St., Watseka, Ill. (Chemistry.) (1927.)
Crummer, Mrs. Emma C., 134 S. Kenilworth Ave., Oak Park, Ill. (Botany.) (1925.)
Culler, Elmer A., Ph. D., University of Illinois, Urbana, Ill. (Psychology.) (1927.)
Currens, Frederick Hawley, Ph. D., 130 N. Normal St., Macomb, Ill. (Chemistry.) (1914.)
Curtis, George M., Ph. D., M. D., University of Chicago, Chicago, Ill. (Anatomy.) (1927.)
Danheim, Bertha, M. S., High School, LaSalle, Ill. (Zoology.) (1928.)
Dappert, A. F., 716 Fayette St., Springfield, Ill. (Engineering.) (1929.)
Darling, Elton R., Ph. D., P. O. Box 825, Danville, Ill. (Chemistry.) (1920.)
Dart, Carlton R., 706 Greenleaf Ave., Wilmette, Ill. (Civil Engineering.) (1921.)
Davenport, Eugene, LL. D., Woodland, Mich. (Agriculture.) (1910.)
Day, William B., M. Phar., 715 S. Wood St., Chicago, Ill. (Botany.) (1927.)
Deam, Hon. Chas. C., M. A., Bluffton, Ind. (Forestry, Flora.) (1921.)
Dean, Ella R., B. Ed., 407 S. Elliott St., Olney, Ill. (Chemistry.) (1921.)
DeLee, Jos. B., M. A., M. D., 5028 Ellis Ave., Chicago, Ill. (Medicine.) (1921.)
DeLoach, R. J. H., M. A., 5541 Dorchester, Chicago, Ill. (Botany, Soils, Economics.) (1926.)
Dempster, A. J., Ph. D., University of Chicago, Chicago, Ill. (Physics.) (1921.)
De Ryke, Willis, Ph. D., Illinois Woman's College, Jacksonville, Ill. (Biology.) (1927.)
De St. Cyr, William H., D. O., 30 N. Michigan Ave., Chicago, Ill. (Medical Science, Physics.) (1927.)
DeTurk, Ernest E., Ph. D., 306 Agric. Bldg., University of Illinois, Urbana, Ill. (Agriculture.) (1920.)
Dickson, Don F., D. Chiro., Lewistown, Ill. (Archeology.) (1929.)
Diits, Charles D., A. B., 3121 Fairfield Ave., Ft. Wayne, Ind. (Chemistry.) (1921.)
Dimmer, Elizabeth, 2722 N. Kimball Ave., Chicago, Ill. (Botany.) (1929.)
Dodd, Fred O., 210 E. Green St., Champaign, Ill. (Entomology.) (1929.)
Dodge, Lawrence E., B. S., Community High School, Gillespie, Ill. (Chemistry.) (1926.)
Donoghue, James, 5538 Magnolia Ave., Chicago, Ill. (Chemistry.) (1929.)
Donoghue, Julia O., 5538 Magnolia Ave., Chicago, Ill. (Nature Study.) (1927.)
Donoghue, Mary, 5538 Magnolia Ave., Chicago, Ill. (Botany.) (1929.)
Downie, Thos. R., 1216 N. Kellogg St., Galesburg, Ill. (Geology.) (1923.)
Downing, Elliot R., Ph. D., University of Chicago, Chicago, Ill. (Zoology.) (1913.)

Dufford, R. T., M. S., University of Missouri, Columbia, Mo. (Physics.) (1918.)
Dungan, Geo. H., Ph. D., University of Illinois, Urbana, Ill. (Plant Physiology.) (1927.)
Earle, C. A., M. D., DesPlaines, Ill. (Botany.) (1920.)
East, Clarence W., M. D., F. A. S. C., 326 W. Jackson St., Springfield, Ill. (Preventive Medicine.) (1921.)
Eaton, S. H., 1301 9th St., Lawrenceville, Ill. (Botany.) (1929.)
Eaton, Scott V., Ph. D., University of Chicago, Chicago, Ill. (Botany.) (1925.)
Eddy, Samuel, Ph. D., University of Minnesota, St. Paul, Minn. (Biology.) (1925.)
Edstrom, E. E., 5938 Dakin St., Chicago, Ill. (Chemistry.) (1929.)
Edwards, Linden F., Ph. D., Dept. of Anatomy, Ohio State University, Columbus, Ohio. (Zoology.) (1926.)
Ehrman, E. H., M. E., 1020 S. Homan Ave., Chicago, Ill. (Physics.) (1920.)
Elfrig, C. W. G., 1029 Monroe Ave., River Forest, Ill. (Ornithology, Botany, Zoology.) (1920.)
Eklund, Edwin G., M. A., 1451 S. Lincoln St., Springfield, Ill. (Psychology.) (1925.)
Eldredge, Arthur G., University of Illinois, Urbana, Ill. (Photography.) (1916.)
Eller, W. H., B. S., 230 N. Ward St., Macomb, Ill. (Physics.) (1924.)
Ellison, Lewis M., 214 W. Kinzie St., Chicago, Ill. (Engineering.) (1927.)
Englis, Duane T., Ph. D., University of Illinois, Urbana, Ill. (Chemistry.) (1917.)
Epstein, Arthur L., B. S., High School, Peoria, Illinois. (Biology.) (1929.)
Erffmeyer, Clarence E., Ph. D., North Central College, Naperville, Ill. (Education.) (1928.)
Ernest, Mary R., 463 W. Decatur St., Decatur, Ill. (Physiology.) (1928.)
Esheiman, H. C., M. S., Lee's College, Jackson, Ky. (Chemistry.) (1929.)
Esmaker, John Benjamin, M. A., 1076 W. Roosevelt Road, Chicago, Ill. (Physics.) (1926.)
Essex, Hiram E., Ph. D., 1127 W. Center St., Rochester, Minn. (Zoology.) (1928.)
Evans, Frank N., M. D., 407 S. Seventh St., Springfield, Ill. (Medicine.) (1925.)
Falk, I. S., Ph. D., University of Chicago, Chicago, Ill. (Bacteriology, Hygiene.) (1925.)
Farnam, Bertha L., Carbondale, Ill. (Biology.) (1927.)
Fasoldt, Karl N., B. Ph., Johnston City, Ill. (Botany.) (1927.)
Faught, Eva E., Dept. of Health, Carbondale, Ill. (Bacteriology.) (1925.)
Faust, Mildred E., M. S., 848 Lancaster Ave., Syracuse, N. Y. (Botany.) (1925.)
Ferguson, Harry F., B. S., Dept. Public Health, Springfield, Ill. (Sanitary Engineering.) (1925.)
Fetter, Dorothy, M. S., Winthrop College, Rock Hill, S. Car. (Physiology.) (1926.)
Finley, C. W., Ph. D., State College of Education, Upper Montclair, N. J. (Zoology.) (1910.)
Fisher, D. Jerome, Ph. D., Rosenwald Hall, University of Chicago, Chicago, Ill. (Geology.) (1926.)
Flint, W. P., M. S., State Entomologist, 1006 S. Orchard St., Urbana, Ill. (Entomology.) (1914.)
Foreman, Blye E., B. Ed., Pearl, Ill. (Zoology.) (1927.)
Franing, E. C., M. D., 404 Bank of Galesburg Bldg., Galesburg, Ill. (Medicine.) (1921.)
Franing, Russel, B. A., Dundee Community High School, Dundee, Ill. (Chemistry.) (1924.)
Frank, O. D., M. S., 6207 Kimbark Ave., Chicago, Ill. (Biology.) (1918.)
Frazier, John C., M. A., 1010 Prairie St., Bloomington, Ill. (Botany.) (1928.)
Freeman, Harriette, M. S., 111 S. Eastern St., Joliet, Ill. (Botany.) (1927.)
French, G. H., M. A., Herrin Hospital, Herrin, Ill. (Botany, Entomology.) (1921.)
Friedli, F. J., M. S., 149 So. Penn. St., Belleville, Ill. (Zoology.) (1928.)
Frison, Theodore H., Ph. D., 316-A Natural History Bldg., University of Illinois, Urbana, Ill. (Entomology, General Biology.) (1917.)
Fryxell, Fritiof M., M. A., 715 3rd St., Moline, Ill. (Geology.) (1925.)
Funk, Donald S., B. A., Sangamo Electric Co., Springfield, Ill. (Physics.) (1925.)
Galajikian, A. S., M. S., Knox College, Galesburg, Ill. (Physics.) (1929.)
Gamble, Faith, 206 Clinton Ave., Oak Park, Ill. (General Interest.) (1926.)
Garnett, H. W. B. S., 205½ North St., Normal, Ill. (Chemistry.) (1927.)
Gault, B. T., 564 N. Main St., Glen Ellyn, Ill. (Ornithology.) (1910.)
Gault, Robert H., Ph. D., Northwestern University, Evanston, Ill. (Psychology.) (1926.)
Gay, Berry E., Ph. G., 720 W. Olive St., Decatur, Ill. (Bacteriology.) (1927.)
Geauque, H. A., M. S., Lombard College, Galesburg, Ill. (Chemistry.) (1923.)
George, Melderine, B. S., 613 E. Grove St., Galesburg, Ill. (Home Economics.) (1929.)
Gersbacher, Willard M., B. Ed., 508 W. Pecan St., Carbondale, Ill. (Zoology.) (1926.)

Givens, Harry V., B. S., Midland Ave., Joliet, Ill. (Biology.) (1927.)
Glattfeld, J. W. E., Ph. D., University of Chicago, Chicago, Ill. (Chemistry.) (1921.)
Goldstine, Mark T., M. D., 25 E. Washington St., Chicago, Ill. (Medicine.) (1926.)
Goode, J. Paul, Ph. D., 6227 Kimbark Ave., Chicago, Ill. (Geography.) (1912.)
Gorrell, T. J. H., M. D., Chicago Heights, Ill. (Medicine.) (1921.)
Gould, H. W., 517 S. 3rd St., DeKalb, Ill. (Chemistry.) (1929.)
Gould, Wm. C., M. A., 625 DeKalb Ave., DeKalb, Ill. (Geography.) (1925.)
Gradle, Harry S., M. D., 154 Vine Ave., Highland Park, Ill. (Opthalmology.) (1920.)
Graham, Robert D. V. M., 105 Animal Pathology, University of Illinois, Urbana, Ill. (Pathology.) (1910.)
Graham, V. O., M. S., 4028 Grace St., Chicago, Ill. (Botany.) (1926.)
Greathouse, G. A., B. Ed., 404 Nat. Hist. Bldg., Urbana, Ill. (Biology.) (1927.)
Green, Helen R., B. A., R. F. D. No. 8, Jacksonville, Ill. (General Interest.) (1927.)
Greenhill, J. P., M. D., 426 E. 51st St., Chicago, Ill. (Embryology.) (1928.)
Greenman, J. M., Ph. D., Missouri Botanical Garden, St. Louis, Mo. (Botany.) (1911.)
Greer, Frank E., M. S., 5454 Kimbark Ave., Chicago, Ill. (Bacteriology.) (1927.)
Griffin, J. P., B. A., 706 S. Cobs St., Urbana, Ill. (Geology.) (1927.)
Gronemann, Carl F., 310 N. Liberty St., Elgin, Ill. (Artist, Naturalist.) (1921.)
Grove, P. F., M. A., 603 E. Ridge St., Mt. Carroll, Ill. (Botany.) (1926.)
Gueffroy, Edna M., M. A., 207 W. Graham St., Bloomington, Ill. (Geography.) (1928.)
Gunbart, Louis F., 505 S. Randolph St., Macomb, Ill. (Botany.) (1929.)
Haas, Flora Anderson, Ph. D., 736 E. 3rd St., Bloomington, Ind. **(Botany.)** (1925.)
Haas, William H., Ph. D., Northwestern University, Evanston, Ill. (Geography.) (1914.)
Haefuer, R., M. A., 1538 4th St., Charleston, Ill. (Psychology.) (1926.)
Hagler, E. S., M. D., 1900 W. Lawrence Ave., Springfield, Ill. (Optics.) (1910.)
Hague, Stella M., Ph. D., Dept. of Botany, University of Illinois, Urbana, Ill. (Botany.) (1929.)
Haldeman, W. S., M. A., 305 N. Second St., Monmouth, Ill. (Chemistry.) (1928.)
Hall, Henry, M. A., Latham, Ill. (Zoology.) (1928.)
Hamilton, Angelina G., M. D., State Hospital, Anna, Ill. (Psychiatry.) (1926.)
Hamp, Mattie S., B. S., Rosiclare High School, Rosiclare, Ill. (Biology.) (1926.)
Hanke, Martin E., Ph. D., Dept. of Physiological Chemistry, University of Chicago, Chicago, Ill. (Physiology, Chemistry.) (1927.)
Hanks, Mary E., M. D., 307 N. Michigan Ave., Chicago, Ill. (Roentgentherapy.) (1927.)
Hansen, Paul, 1741 Avenue H, Chicago, Ill. (Geology.) (1927.)
Hansen, Paul, 6 No. Michigan Ave., Chicago, Ill. (Sanitation.) (1913.)
Hardin, Sarah M., B. Ph., 402 W. Walnut St., Carbondale, Ill. (Biology.) (1924.)
Harding, H. A., Ph. D., 685 Mullett St., Detroit, Mich. (Bacteriology.) (1916.)
Hargitt, T. F., Ph. D., Dept. of Physics, Illinois Wesleyan College, Bloomington, Ill. (Physics.) (1928.)
Harland, Marion B., M. S., 655 Old Agriculture Bldg., University of Illinois, Urbana, Ill. (Soils.) (1925.)
Harnly, John W., 1026 Poplar St., Waukegan, Ill. (Chemistry.) (1929.)
Harrabin, H. W., 825 W. Carroll St., Macomb, Ill. (Chemistry.) (1929.)
Hartman, Ernest, Sc. D., Lingnan University, Canton, China. (Parasitology.) (1927.)
Harvey, Alice L., B. A., 2036 Spruce St., Murphysboro, Ill. (Chemistry.) (1926.)
Hatfield, E. Frances, M. A., Normal University, Normal, Ill. (Biology.) (1928.)
Haupt, Arthur W., Ph. D., University of California, Los Angeles, Calif. (Botany.) (1912.)
Hawkes, Joseph Buckley, B. A., Dept. of Botany, University of Chicago, Chicago, Ill. (Botany.) (1925.)
Hay, Logan, B. A., 1220 S. Grand Ave., W., Springfield, Ill. (Mathematics.) (1925.)
Hayes, Wm. P., Ph. D., 300 Natural History Bldg., Urbana, Ill. (Entomology.) (1926.)
Heath, Geo. D., M. D., 1308 N. Main, Bloomington, Ill. (Epedemiology.) (1928.)
Hedrick, Leslie, B. A., 410 Conover Ave., Eureka, Ill. (Zoology.) (1927.)
Heflin, H. N., M. D., Kewanee, Ill. (Medicine.) (1921.)

Hemenway, Henry B., M. D., 620 Amos Ave., Springfield, Ill. (Public Health.) (1918.)
Henbest, Lloyd G., M. A., 305 Ceramics Bldg., University of Illinois, Urbana, Ill. (Geology, Biology.) (1927.)
Henderson, Mrs. Bessie Green, M. A., 1305 Euclid Ave., Boulder, Colo. (Zoology.) (1911.)
Henderson, Lena B., M. S., Randolph-Macon College, Lynchberg, Va. (Botany.) (1926.)
Henderson, Luther B., M. A., Davidson College, Davidson, N. Car. (Psychology.) (1925.)
Hendricks, Mrs. Nina Wicks, M. S., 405 Fifth Ave., Mendota, Ill. (Zoology.) (1927.)
Henkel, H., B., M. D., 401 E. Capitol Ave., Springfield, Ill. (Medicine.) (1925.)
Herrick, C. Judson, Ph. D., University of Chicago, Chicago, Ill. (Anatomy.) (1920.)
Herrick, Julia F., M. A., Mayo Foundation, Rochester, Minn. (Physics.) (1926.)
Herron, James C., M. E., 1417 W. Jackson Blvd., Chicago, Ill. (Illuminating Engineer.) (1926.)
Herskovits, Melville J., Ph. D., Northwestern University, Evanston, Ill. (Anthropology.) (1929.)
Hesh, Claude J., B. S., 209 N. Normal Ave., Macomb, Ill. (Geography.) (1929.)
Hetler, Rossieene A., Ph. D., Agriculture Experiment Station, University of Illinois, Urbana, Ill. (Physiology, Chemistry.) (1929.)
Hieronymus, R. E., LL. D., 109 New Agriculture Bldg., University of Illinois, Urbana, Ill. (1926.)
Higginson, Glenn D., Ph. D., 1117 W. Illinois St., Urbana, Ill. (Psychology.) (1927.)
Higley L. A., Ph. D., Box 776, Wheaton, Ill. (Chemistry.) (1926.)
Hildebrand, L. E., M. A., 1620 Ridge Ave., Evanston, Ill. (Zoology.) (1911.)
Hill, Joseph H., B. S., 3004 N. Racine Ave., Chicago, Ill. (Chemistry.) (1929.)
Hines, Murray A., Ph. D., 1416 Hinman Ave., Evanston, Ill. (Chemistry.) (1914.)
Hinrichs, Marie A., Ph. D., University of Chicago, Chicago, Ill. (General Physiology.) (1926.)
Hockenyos, Geo. L., 1003 Oregon St., Urbana, Ill. (Botany.) (1927.)
Hoehn, B. Eva, B. S., 703 S. West St., Carlinville, Ill. (Biology.) (1929.)
Hoffmann, Frank F., M. D., 3117 Logan Blvd., Chicago, Ill. (Surgery.) (1921.)
Hoheisel, William, B. A., 301 Nat. Hist. Bldg., University of Illinois, Urbana, Ill. (Zoology.) (1929.)
Holmes, Harriet F., B. A., South Batavia Rd., Batavia, Ill. (Plant Pathology.) (1927.)
Holmes, Manfred J., B. L., 703 Broadway, Normal, Ill. (Sociology, Education.) (1920.)
Holmes, Ralph R., M. D., 458 W. 61st St., Chicago, Ill. (Astronomy.) (1926.)
Holtz, F. C., B. S., 1358 Dial Court, Springfield, Ill. (Mathematics, Physics.) (1925.)
Honey, Edwin E., Ph. D., Escola Agricola, Piracicabo, Sao Paulo, Brazil, S. A. (Plant Pathology, Botany, Entomology.) (1921.)
Hopkins, B. Smith, Ph. D., 706 W. California St., Urbana, Ill. (Inorganic Chemistry.) (1920.)
Horrell, C. R., B. S., Sangamo Electric Co., Springfield, Ill. (Electrical Engineering.) (1925.)
Hottes, Frederick C., M. A., James Millikin University, Decatur, Ill. (Biology.) (1929.)
Houdek, Paul, B. S., 710 N. Gross St., Robinson, Ill. (Biology.) (1928.)
Howard, W. V., Ph. D., University of Illinois, Urbana, Ill. (Geology.) (1928.)
Howe, Sister M. Virginia, 617 S. State Ave., Freeport, Ill. (Physics, Biology.) (1929.)
Howe, Samuel W., B. Ed., 311 N. 14th St., Herrin, Ill. (1925.)
Hudelson, C. W., B. Agric., 206 S. Main St., Normal, Ill. (Agriculture.) (1921.)
Huey, Walter B., M. D., Elgin, Joliet & Eastern Ry., Joliet, Ill. (Medicine.) (1921.)
Hufford, G. N., B. A., 216 Seeser, Joliet, Ill. (Botany.) (1927.)
Hull, Thos. G., Ph. D., State Board of Health, Springfield, Ill. (Health.) (1921.)
Hungerford, Warren H., 1920 City Hall Square Bldg., Chicago, Ill. (Physics.) (1927.)
Hunt, L. W., B. S., Galesburg High School, Galesburg, Ill. (Chemistry.) (1928.)
Hunter, Geo. W., III, Ph. D., Wesleyan University, Middletown, Conn. (Zoology.) (1928.)
Illinois State Library, State House, Springfield, Ill. (1921.)
Isenbarger, Jerome, B. S., Crane Junior College, Chicago, Ill. (Zoology.) (1921.)
Jacobi, Wm. H., M. E., Springfield Boiler Co., Springfield, Ill. (Physical Chemistry.) (1925.)

Jacobs, Margaret C., 413 Leland St., Baraboo, Wis. (Botany.) (1925.)
Janaurius, Sister M., M. A., 106 W. Chestnut St., Bloomington, Ill. (Physics.) (1928.)
Jane, Wm. T., 5 N. Wabash Ave., Chicago, Ill. (Physics, Bausch & Lomb Opt. Co.) (1921.)
Janson, Ardylle A., 636 Church St., Evanston, Ill. (Bacteriology.) (1927.)
Jelliff, Fred R., M. A., Editor, Daily Register-Mail, Galesburg, Ill. (Geology.) (1917.)
Jenks, Ira J., M. S., Northern Illinois State Teachers' College, DeKalb, Ill. (Chemistry.) (1922.)
Jensen, Jens, Ravinia, Ill. (Geology, Botany.) (1921.)
Johnson, George F., 625 Black Ave., Springfield, Ill. (Astronomy.) (1914.)
Johnson, John H., M. A., Supt. of Schools, Tremont, Ill. (Biology.) (1923.)
Johnson, T. Arthur, M. D., 503 7th St., Rockford, Ill. (Medicine, Science, Surgery.) (1920.)
Jones, Elmer E., Ph. D., Northwestern University, Evanston, Ill. (Mental Development, Heredity.) (1920.)
Jones, Lloyd, 614 W. 3rd Ave., Macomb, Ill. (General Interest.) (1929.)
Jurica, Hilary S., Ph. D., St. Procopius College, Lisle, Ill. (Botany.) (1922.)
Kaplan, Bertha, M. S., 1350 S. Avers Ave., Chicago, Ill. (Bacteriology, Parasitology.) (1927.)
Karr, Gertrude, B. A., State Teachers' College, Fredericksburg, Va. (Botany.) (1925.)
Karraker, Edward L., Jonesboro, Ill. (Forestry.) (1921.)
Kempton, F. E., Ph. D., Mt. Union College, Alliance, Ohio. (Plant Pathology.) (1917.)
Kennedy, E. V., B. Ed., Ava, Ill. (Biology.) (1925.)
Kennicott, Ransom, 547 Cook Co. Bldg., Chicago, Ill. (Forestry.) (1921.)
Kent, R. A., Ph. D., 1904 Lauderdale Drive, Louisville, Ky. (Education.) (1926.)
Keyes, D. B., Ph. D., 107 Chem. Bldg., University of Illinois, Urbana, Ill. (Chemistry.) (1927.)
Kibbe, Alice L., Ph. D., Carthage College, Carthage, Ill. (Botany.) (1925.)
Kienholz, Aaron Raymond, Ph. D., 606 Washington St., Urbana, Ill. (Botany.) (1925.)
Kirby, E. R., B. S., 1101 S. University Ave., Normal, Ill. (Chemistry.) (1928.)
Kirkpatrick, Amy R., Anna, Ill. (Artist.) (1926.)
Kirn, George H., Ph. D., D. D., North Central College, Naperville, Ill. (Psychology, Philosophy.) (1923.)
Kline, R. G., M. D., Hoopeston, Ill. (Medicine.) (1921.)
Koch, Fred Conrad, Ph. D., University of Chicago, Chicago, Ill. (Physiological Chemistry.) (1920.)
Koontz, D. Lionel, M. E., 902 Reba Place, Evanston, Ill. (Mechanical Engineer.) (1926.)
Kordsiemon, Anna M., 825 Washington St., Quincy, Ill. (General Interest.) (1926.)
Krause, Heinrich, D. D. S., 2027 W. 18th Place, Chicago, Ill. (Anthropology.) (1926.)
Kremers, H. C., B. S., 712 S. Broadway, Urbana, Ill. (Chemistry.) (1929.)
Krenz, Mathilde H., Ph. D., Adelphi College, Garden City, L. I., N. Y. (Botany.) (1925.)
Kuh, Sidney, M. D., 8148 Evans Ave., Chicago, Ill. (Medicine.) (1911.)
Kyle, Alfred J., Momence, Ill. (Herpetology.) (1928.)
Lackie, G. D., M. D., Springfield, Ill. (Medicine.) (1927.)
Lacy, Robert, M. E., 1354 Dial Court, Springfield, Ill. (Engineer.) (1925.)
Lake, Mae M., B. Ed., 203 Grand Ave., Lincoln, Ill. (Biology.) (1927.)
Lamar, J. Everts, B. S., State Geological Survey Div., Urbana, Ill. (Geology.) (1924.)
Lambert, Earl L., B. S., 217 N. 1st St., Carthage, Ill. (Botany, Zoology.) (1917.)
Lamkey, Ernest, Ph. D., 505 S. Fall Ave., Normal, Ill. (Botany.) (1928.)
Landon, R. E., 4122 N. Keystone Ave., Chicago, Ill. (General Interest.) (1926.)
Lanphier, Robert C., B. Ph., Sangamo Electric Co., Springfield, Ill. (Electricity.) (1914.)
Lansing, W. D., B. S., 1605 N. Neil St., Champaign, Ill. (Physics.) (1928.)
Large, J. M., B. A., 105 Mound St., Joliet, Ill. (Geography.) (1927.)
Larned, S. J., M. E., R. F. D. No. 3, Saugerties, N. Y. (Physics.) (1926.)
Larson, E. A., M. S., 115 Cagwin St., Joliet, Ill. (Chemistry.) (1927.)
Larson, Karl G., B. A., Augustana College, Rock Island, Ill. (Chemistry.) (1917.)
Lathrop, W. G., Principal Township High School, Johnston City, Ill. (Geology, Geography.) (1922.)
Laufer, Berthold, Ph. D., Field Museum, Chicago, Ill. (Archaeology.) (1925.)
Laves, Kurt, Ph. D., University of Chicago, Chicago, Ill. (Astronomy, Mathematics.) (1920.)
Leech, Bert S., M. A., Highland Park, Ill. (Biology.) (1927.)
Leighton, Morris Morgan, Ph. D., Chief, Illinois Geological Survey Division, Urbana, Ill. (Geology.) (1920.)

Leonard, Thos. H., M. D., 509 S. 6th St., Springfield, Ill. (Medicine.) (1925.)
Lessman, Lem. L., 412 N. Monroe St., Peoria, Ill. (General Interest.) (1926.)
Lewis, Howard B., Ph. D., University of Michigan, Medical School, Ann Arbor, Michigan. (Physiology, Chemistry.) (1920.)
Lewis, Julian H., Ph. D., M. D., Ricketts Laboratory, University of Chicago, Chicago, Ill. (Pathology.) (1921.)
Linder, O. A., 208 N. Wells St., Chicago, Ill. (General Interest.) (1910.)
Link, T. A., Ph. D., Geology Department, Imperial Oil, Ltd., Calgary, Alberta Canada. (Geology.) (1926.)
Linkins, R. H., M. A., 706 Broadway, Normal, Ill. (Zoology.) (1917.)
Litchey, Daniel, M. D., 1920 Harlem Blvd., Rockford, Ill. (Anthropology.) (1926.)
Loach, R. J., M. A., 5541 Dorchester Ave., Chicago, Ill. (Biology.) (1927.)
Lockie, G. D., M. D., First National Bank Bldg., Springfield, Ill. (Archeology.) (1927.)
Lodge, Fred S., B. S., 423 S. Stone Ave., LaGrange, Ill. (Zoology, Agriculture, Chemistry.) (1926.)
Logan, Hay, B. A., 1220 S. Grand Ave., Springfield, Ill. (Mathematics.) (1927.)
Logsdon, Mrs. M. I., Ph. D., University of Chicago, Chicago, Ill. (Mathematics.) (1923.)
Longbons, Elizabeth, B. S., 2 E. Walnut St., Harrisburg, Ill. (Chemistry.) (1925.)
Longden, A. C., Ph. D., Knox College, Galesburg, Ill. (Physics.) (1917.)
Lukens, Herman T., Ph. D., Francis W. Parker School, Chicago, Ill. (Geography.) (1920.)
Lundgren, Alice D., 4840 Karlov Ave., Chicago, Ill. (Geology.) (1929.)
Lutes, Nell, B. S., 1595 Atlantic St., Dubuque, Iowa. (Chemistry.) 1912.)
Lyon, William L., 124 Washington St., Waukegan, Ill. (Ornithology.) (1926.)
MacDowell, Charles H., Sc. D., 111 W. Jackson Blvd., Chicago, Ill. (Chemistry.) (1926.)
Mackie, Arthur D., 400 E. Monroe St., Springfield, Ill. (Electricity.) (1915.)
MacMillan, W. D., Ph. D., University of Chicago, Chicago, Ill. (Astronomy.) (1922.)
Madison, Wm. D., M. D., Eureka, Ill. (Medicine.) (1921.)
Magill, Henry P., 175 W. Jackson Blvd., Chicago, Ill. (Geology, Sociology, Finance.) (1920.)
Mahoney, Sister Myra, B. A., 856 W. Garfield Blvd., Chicago, Ill. (Chemistry.) (1928.)
Main, Helen, B. S., Gladstone Hotel, Chicago, Ill. (Botany.) (1927.)
Malinovsky, A., B. S., Washington Iron Works, Los Angeles, Calif. (Chemistry.) (1920.)
Mann, A. L., M. D., Box 106, Elgin, Ill. (Medicine.) (1921.)
Mann, Jessie R., B. S., Northern Illinois State Teachers' College, DeKalb, Ill. (Biology.) (1923.)
Manning, W. E., Ph. D., Smith College, Northampton, Mass. (Botany.) (1928.)
Marks, Sarah, B. A., Pecatonica, Ill. (Biology.) (1917.)
Markus, H. C., B. A., 321 Nat. Hist. Bldg., University of Illinois, Urbana, Ill. (Geology.) (1926.)
Martin, George W., Ph. D., University of Iowa, Iowa City, Ia. (Biology.) (1923.)
Marvel, Carl S., Ph. D., University of Illinois, Urbana, Ill. (Chemistry.) (1927.)
Mason, Arthur J., Homewood, Ill. (General Interest.) (1921.)
Mason, Carol, M. A., Milwaukee Downer College, Milwaukee, Wis. (Geography, Botany.) (1926.)
Maynard, M. M., M. A., Monmouth College, Monmouth, Ill. (Psychology, Education.) (1927.)
McAvoy, Blanche, M. A., Illinois State Normal University, Normal, Ill. (Botany.) (1928.)
McClure, S. M., M. S., McKendree College, Lebanon, Ill. (Chemistry.) (1921.)
McCormick, Robert N., M. S., 301 Nat. Hist. Bldg., University of Illinois, Urbana, Ill. (Zoology.) (1929.)
McCoy, Herbert N., Ph. D., 2537 Fifth Ave., Los Angeles, Calif. (Chemistry.) (1914.)
McCulloch, E. C., D. V. M., Box 55, Auburn, Alabama. (Parasitology.) (1927.)
McDavitt, Neva, B. Ed., 303 North St., Normal, Ill. (Geography.) (1925.)
McEvoy, S. Aleta, B. S., Rockford High School, Rockford, Ill. (Chemistry.) (1923.)
McGinnis, Helen A., B. S., 6400 S. Maplewood Ave., Chicago, Ill. (General Science.) (1923.)
McKee, W. A., D. D. S., East Side Square, Benton, Ill. (General Interest.) (1922.)
McMaster, Archie J., M. S., The G-M Labs., Inc., 1800 Grace St., Chicago, Ill. (Physics, Chemistry.) (1922.)
Mecham, John B., Ph. D., 118 S. Center St., Joliet, Ill. (General Interest.) (1917.)
Metcalf, C. L., Ph. D., Old Law Bldg., University of Illinois, Urbana, Ill. (Entomology.) (1925.)

Metzner, Albertine E., M. S., State Teachers' College, Edinboro, Pa. (Geology, Physics.) (1918.)
Michaels, Walter H., Ph. D., Dept. of Botany, University of Illinois, Urbana, Ill. (Plant Physiology.) (1929.)
Miller, Isiah Leslie, M. A., College Station, Box 53, Brookings, So. Dakota. (Mathematics, Chemistry.) (1920.)
Miller, P. H., B. Ed., High School, Henning, Ill. (Biology.) (1920.)
Miller, R. B., M. F., 121 Capitol Bldg., Department of Conservation, Springfield, Ill. (Forestry, Ecology.) (1920.)
Milum, Vern G., Ph. D., Vivarium Bldg., University of Illinois, Urbana, Ill. (Agriculture.) (1928.)
Mitchell, Catharine, B. A., 144 Fairbank Road, Riverside, Ill. (Botany, Ornithology.) (1925.)
Mongerson, Oscar V., B. S., Supt. of Schools, Chenoa, Ill. (Physics.) (1925.)
Montgomery, C. E., M. S., Northern Illinois State Teachers' College, DeKalb, Ill. (Biology.) (1917.)
Moore, W. W., B. Agric., R. F. D., Rushville, Ill. (Agriculture.) (1929.)
Moorehead, W. K., Sc. D., Andover, Mass. (Anthropology.) (1929.)
Morgan, John J. B., Ph. D., Northwestern University, Evanston, Ill. (Psychology.) (1926.)
Morgan, Wm. E., M. D., 1016 Hyde Park Blvd., Chicago, Ill. (Medicine.) (1921.)
Morgenstern, Edward M., 2710 Jackson Blvd., Chicago, Ill. (Physiology.) (1929.)
Mortimer, F. S., Ph. D., Illinois Wesleyan University, Bloomington, Ill. (Chemistry.) (1928.)
Moulton, C. Robert, Ph. D., 5712 Kenwood Ave., Chicago, Ill. (Chemistry.) (1926.)
Moulton, F. R., Ph. D., Sc. D., 327 S. LaSalle St., Chicago, Ill. (Astronomy.) (1912.)
Mumford, H. W., D. Agric., University of Illinois, Urbana, Ill. (Agriculture.) (1910.)
Murrah, Frank C., M. D., 105½ N. Park Ave., Herrin, Ill. (Medicine.) (1921.)
Murray, A. N., Ph. D., 2432 E. 8th St., Tulsa, Okla. (Geology.) (1926.)
Murray, Sister Mary Samuela, B. A., 856 W. Garfield Blvd., Chicago, Ill. (Physics.) (1928.)
Mylius, L. A., M. E., 704 Shell Bldg., St. Louis, Mo. (Geology.) (1921.)
Nadler, Walter H., M. D., Northwestern University Medical School, Chicago, Ill. (Medicine.) (1921.)
Nash, Edna L., B. A., 220 College Ave., DeKalb, Ill. (Geography.) (1927.)
Neave, Sidney Lionel, M. A., 1208 W. Clark St., Urbana, Ill. (Chemistry.) (1926.)
Needham, Claude E., B. S., University Hall, Evanston, Ill. (Geology.) (1929.)
Neifert, Ira E., M. S., Knox College, Galesburg, Ill. (Chemistry.) (1917.)
Nelson, C. Z., 534 Hawkinson Ave., Galesburg, Ill. (Botany.) (1917.)
Nelson, Emil A., M. E., 1126 S. Seventh St., Springfield, Ill. (Engineering.) (1924.)
Neureiter, Paul R., Ph. D., Western Illinois State Teachers' College, Macomb, Ill. (Chemistry.) (1928.)
Neville, Russell T., B. S., Kewanee, Ill. (Geology.) (1929.)
Newcomb, Rexford, M. Arch., University of Illinois, Urbana, Ill. (Architecture,.) (1920.)
Newell, M. J., M. A., 2226 Hartzell Ave., Evanston, Ill. (Education.) (1920.)
Newman, H. H., Ph. D., University of Chicago, Chicago, Ill. (Zoology.) (1912.)
Nicholson, F. M., Ph. D., M. D., 5 N. Wabash Ave., Chicago, Ill. (Anatomy.) (1920.)
Noe', Adolf Carl, Ph. D., University of Chicago, Chicago, Ill. (Paleobotany,) (1923.)
Noyes, Wm. Albert, Jr., Sc. D., Brown University, Providence, R. I. (Chemistry.) (1925.)
Nuttall, Mrs. Olive, B. S., Springfield High School, Springfield, Ill. (Botany.) (1928.)
Obenchain, Jeanette Brown, M. D., Hotel Del Prado, Chicago, Ill. (Anatomy.) (1921.)
Oesterling, H. C., B. A., Natural History Survey, Urbana, Ill. (Ecology.) (1928.)
Ogilvy, Robert S., B. Arch., 411 Taylor Ave., Glen Ellyn, Ill. (Architecture.) (1921.)
O'Hanlon, Sister Mary Ellen, Ph. D., Rosary College, River Forest, Ill. (Biology.) (1928.)
Olson, George A., M. S., Olson Research Labs., Park Ridge, Ill. (Chemistry.) (1926.)
Ozment, Arel, 806 Washington Ave., Johnson City, Ill. (General Interest.) (1921.)
Packard, W. H., Ph. D., Bradley Polytechnical Institute, Peoria, Ill. (Biology.) (1909.)
Paddock, Walter R., M. D., 904 State St., Lockport, Ill. (Medicine.) (1921.)
Paine, Leland S., M. A., 918 S. Fell Ave., Normal, Ill. (Geography.) (1927.)
Paintin, Mrs. Ruth D., 827 Ridge Ave., Evanston, Ill. (Botany.) (1928.)

Palmer, Charles Shattuck, Ph. D., 1704 Hinman Ave., Evanston, Ill. (Chemistry. (1925.)
Parkhill, John L., 148 N. Institute Ave., Peoria, Ill. (Physics.) (1929.)
Parr, Rosalie M., Ph. D., 1107 W. Oregon St., Urbana, Ill. (Chemistry.) (1926.)
Parson, S. F., M. S., Northern State Teachers' College, DeKalb, Ill. (Mathematics.) (1922.)
Paton, Robert F., Ph. D., 1005 S. Busey St., Urbana, Ill. (Physics.) (1928.)
Patterson, Alice J., M. S., Illinois State Normal University, Normal, Ill. (Entomology, Nature Study.) (1910.)
Patterson, Cecil F., Ph. D., University of Saskatchewan, Saskatoon, Saskatchewan, Canada. (Botany.) (1920.)
Patton, Charles L., M. D., 612 Myers Bldg., Springfield, Ill. (Medicine.) (1925.)
Patton, Fred P., M. D., Glencoe, Ill. (Medicine.) (1921.)
Paul, Edna, 714 W. California St., Urbana, Ill. (Botany.) (1925.)
Peacock, C. Sheller, LL. B., 323 N. Third St., Monmouth, Ill. (Mycology.) (1925.)
Pearsons, H. P., 1816 Chicago Ave., Evanston, Ill. (General Interest.) (1921.)
Penney, Mark Embury, Ph. D., 1441 W. Macon St., Decatur, Ill. (Psychology.) (1926.)
Petefish, Charles, B. A., N. Main St., Winchester, Ill. (Biology.) (1928.)
Peterson, C. Beecher, B. S., 706 Second Ave., Joliet, Ill. (Geography.) (1927.)
Peterson, Oliver H., M. A., School of Education, James Millikin University, Decatur, Ill. (Psychology.) (1928.)
Pfanstiehl Carl, Wood Path Ave., Highland Park, Ill. (Physics, Chemistry.) (1926.)
Phelps, Lillian B., B. S., Golconda, Ill. (Physics.) (1926.)
Phelps, Walter S., D. D. S., 57 Public Square, Monmouth, Ill. (Mycology.) (1925.)
Phipps, Charles Frank, M. S., 342 Grand Ave., Long Beach, Calif. (Physics, Chemistry.) (1917.)
Pieper, Charles J., M. S., University of Chicago, Chicago, Ill. (General Science.) (1921.)
Plapp, F. W., M. S., 4140 N. Keeler Ave., Chicago, Ill. (Botany, Geology.) (1922.)
Platt, Robert S., Ph. D., University of Chicago, Chicago, Ill. (Geography.) (1921.)
Plummer, Beulah A., M. S., College of Industrial Arts, Denton, Texas. (Physiology, Zoology.) (1925.)
Plummer, F. B., 608 W. Seventh St., Austin, Texas. (Geology.) (1926.)
Plummer, Mrs. Helen J., 608 W. Seventh St., Austin, Texas. (Geology.) (1926.)
Poling, J. A., M. D., Henny Bldg., Freeport, Ill. (Medicine.) (1921.)
Pollock, M. D., M. D., 606 Standard Life Bldg., Decatur, Ill. (Medicine, Surgery.) (1920.)
Potter, Franklin C., B. S., 1110 Grant St., Evanston, Ill. (Geography.) (1929.)
Powers, W. E., B. S., University Hall, Evanston, Ill. (Geology.) (1929.)
Quill, Lawrence L., Ph. D., 805 W. Illinois St., Urbana, Ill. (Chemistry.) (1928.)
Quiring, D. P., M. A., University of Illinois, Urbana, Ill. (Zoology.) (1929.)
Quirke, T. T., Ph. D., 234 Nat. Hist. Bldg., University of Illinois, Urbana, Ill. (Geology.) (1921.)
Radcliffe, H. H., M. S., 1346 W. Macon St., Decatur, Ill. (Physics, Chemistry.) (1909.)
Railsback, O. L., M. A., Eastern Illinois State Teachers' College, Charleston, Ill. (Physics.) (1928.)
Rambo, Jessie E., M. A., 208 W. Irving Ave., Normal, Ill. (Chemistry.) (1928.)
Ransom, James H., Ph. D., James Millikin University, Decatur, Ill. (Chemistry.) (1923.)
Ranne, George C., M. A., 405 S. Eastern Ave., Joliet, Ill. (Physics, Chemistry.) (1927.)
Rauth, Andy Fred, McCormick Theological Seminary, 2330 N. Halsted St., Chicago, Ill. (Biology.) (1924.)
Rea, Helen E., 5904 Midway Park, Chicago, Ill. (Chemistry.) (1927.)
Reeder, C. A., Oakdale, Ill. (Botany.) (1929.)
Rew, Irwin, B. A., 217 Dempster St., Evanston, Ill. (General Interest.) (1920.)
Rice, Wm. F., M. A., Wheaton College, Wheaton, Ill. (Physics.) (1909.)
Richardson, Baxter K., B. A., Dept. of Public Health, Springfield, Ill. (Public Health.) (1921.)
Richardson, R. E., M. A., Box 715, Station A, Champaign, Ill. (Zoology.) (1910.)
Rinker, Jacob Arron, B. S., Eureka, Ill. (Physics.) (1923.)
Roberts, Elmer, Ph. D., 508 W. Illinois St., Urbana, Ill. (Genetics.) (1927.)
Robinson, Ray R., M. E., 510 Grant Ave., Joliet, Ill. (Geology.) (1927.)
Rolfe, Mrs. E. P., 825 Ayers Pl., Evanston, Ill. (Geology.) (1929.)
Romer, A. S., Ph. D., University of Chicago, Chicago, Ill. (Paleontology.) (1925.)

Root, Clarence J., U. S. Weather Bureau, Springfield, Ill. (Climatology.) (1913.)
Rose, Dorothy E., B. S., 305 Ceramics Bldg., University of Illinois, Urbana, Ill. (Geology.) (1928.)
Rose, William C., Ph. D., University of Illinois, Urbana, Ill. (Chemistry.) (1924.)
Ross, Herbert H., B. S., Nat. Hist. Survey, Urbana, Ill. (Entomology.) (1928.)
Royce, Bertha M., M. A., 204 N. School St., Normal, Ill. (Zoology.) (1927.)
Sakemiller, Vera M., B. Ed., 1007 S. Low St., Bloomington, Ill. (Biology.) (1927.)
Sallee, Roy M., M. S., Western Illinois State Teachers' College, Macomb, Ill. (Botany, Ornithology.) (1929.)
Salter, Allen, M. D., Lena, Ill. (Medicine.) (1920.)
Sampson, H. C., Ph. D., Ohio State University, Columbus, Ohio. (Botany.) (1912.)
Saunders, Mrs. Amy, M. D., 104 S. Scoville Ave., Oak Park, Ill. (Neurology.) (1928.)
Saunders, Felix, Ph. D., University of Chicago, Chicago, Ill. (Chemistry.) (1928.)
Savage, Margaret, B. S., 613 W. Nevada St., Urbana, Ill. (Botany.) (1925.)
Schantz, Orpheus M., Room 521, 137 S. LaSalle St., Chicago, Ill. (Birds, Plants.) (1920.)
Schaub, Edward L., Ph. D., 3603 Lockwood Ave., Toledo, Ohio. (Psychology.) (1920.)
Schertz, Ray J., B. A., Township High School, Metamora, Ill. (Chemistry.) (1928.)
Schmidt, Otto L., M. D., 5 S. Wabash Ave., Chicago, Ill. (History.) (1921.)
Schmoll, Hazel Marguerite, M. S., Ward, Colo. (Botany.) (1921.)
Schrepfer, Frank A., M. S., University of Pennsylvania, Philadelphia, Pa. (Botany.) (1925.)
Schulz, W. F., Ph. D., University of Illinois, Urbana, Ill. (Physics.) (1910.)
Schwartzberg, Benj., M. S., 1317 S. Homan Ave., Chicago, Ill. (Bacteriology.) (1926.)
Sears, O. H., Ph. D., 606 E. Chalmers St., Champaign, Ill. (Chemistry.) (1922.)
Sellin, Hilding, B. A., Snell Hall, No. 43, University of Chicago, Chicago, Ill. (Geology.) (1927.)
Shank, Marjorie M., M. A., 718 S. Normal St., Carbondale, Ill. (Geography.) (1924.)
Shantz, H. L., Ph. D., Sc. D., University of Arizona, Tucson, Ariz. (Botany.) (1926.)
Sheretz, D. Ransom, B. Ed., 108 Center St., Collinsville, Ill. (Zoology.) (1925.)
Sherwood, G. Ray, B. S., 354 Linden Pl., Decatur, Ill. (Chemistry.) (1929.)
Shull, Charles A., Ph. D., University of Chicago, Chicago, Ill. (Botany, Plant Physiology.) (1924.)
Simer, Dorr M., B. Ed., 1660 N. College St., Decatur, Ill. (Chemistry.) (1928.)
Simer, Parke H., M. S., 303 E. Graham St., Bloomington, Ill. (Zoology.) (1929.)
Simmons, Marguerite L., M. A., 325 Melrose Ave., Centralia, Ill. (Biology.) (1921.)
Simonds, O. C., 1101 Buena Ave., Chicago, Ill. (Botany.) (1920.)
Simons, Etoile B., Ph. D., 2721 E. 75th Place, Chicago, Ill. (Botany.) (1920.)
Singer, H. Douglas, M. D., University of Illinois Medical School, Chicago, Ill. (Psychiatry.) (1920.)
Slye, Maud, B. A., 5836 Drexel Ave., Chicago, Ill. (Zoology.) (1921.)
Smisloff, Walter, 5008 Eddy St., Chicago, Ill. (Chemistry.) (1928.)
Smith, Arthur Bessey, B. S., 2324 Hartzell St., Evanston, Ill. (Telephony.) (1920.)
Smith, Arthur L., B. A., Eureka, Ill. (Biology.) (1927.)
Smith, Clarence R., M. S., Aurora College, Aurora, Ill. (Physics.) (1921.)
Smith, Erman S., B. S., Barrington, Ill. (Nature Study.) (1928.)
Smith, George Hume, Ph. D., University of Missouri, Columbia, Mo. (Botany.) (1921.)
Smith, Grant, Ph. D., Chicago Normal College, Chicago, Ill. (Zoology.) (1921.)
Smith, Guy N., B. S., Rockford High School, Rockford, Ill. (Botany.) (1925.)
Smith, K. K., Ph. D., 2200 Sherman Ave., Evanston, Ill. (Physics.) (1916.)
Smith, R. S., Ph. D., University of Illinois, Urbana, Ill. (Soil Physics, Soil Chemistry.) (1920.)
Snider, Alvin B., M. D., Blue Island, Ill. (Medicine.) (1921.)
Snider, H. J., B. S., University of Illinois, Urbana, Ill. (Soils, Agriculture.) (1921.)
Solheim, Wilhelm G., Ph. D., University of Wyoming, Laramie, Wyo. (Botany.) (1927.)
Sommer, Joseph B., B. S., 202 N. Institute St., Peoria, Ill. (Biology.) (1929.)
Sonnenschein, Robert, M. D., 4518 Woodlawn Ave., Chicago, Ill. (Medicine.) (1920.)
Spooner, Charles S., M. A., 1436 7th St., Charleston, Ill. (Zoology.) (1920.)

Stabin, George W., M. D., First National Bank Bldg., Springfield, Ill. (Medicine.) (1925.)
Stansfield, John, M. S., 902 W. Illinois St., Urbana, Ill. (Geology.) (1925.)
Stark, John Thomas, Ph. D., 900 Greenwood Blvd., Evanston, Ill. (Geology.) (1925.)
Stauffer, Andrew Z., M. S., Crane Junior College, Chicago, Ill. (Botany.) (1928.)
Steagall, Mary M., Ph. D., Southern Illinois State Teachers' College, Carbondale, Ill. (Botany.) (1921.)
Stein, Hilda Anna, B. Ed., Vivarium Bldg., University of Illinois, Urbana, Ill. (Zoology.) (1926.)
Stericker, George B., M. D., First National Bank Bldg., Springfield, Ill. (Medicine.) (1929.)
Stevens, F. L., Ph. D., University of Illinois, Urbana, Ill. (Plant Pathology.) (1914.)
Stillians, A. W., M. D., 911 E. 50th St., Chicago, Ill. (Medicine.) (1921.)
Stout, Gilbert L., M. A., State Natural History Survey, Urbana, Ill. (Botany.) (1927.)
Stover, E. L., Ph. D., Eastern Illinois State Teachers' College, Charleston, Ill. (Botany.) (1924.)
Stover, Mrs. E. L., M. S., 930 Second St., Charleston, Ill. (Botany.) (1923.)
Strong, Harriett, M. S., 702 Maple Ave., Downers Grove, Ill. (Botany.) (1917.)
Struble, R. H., B. A., 4481 Sheridan Ave., Detroit, Mich. (Physics.) (1921.)
Sturm, Kathryn, B. Ed., 608 S. Main St., Anna, Ill. (Zoology.) (1927.)
Swan, W. S., M. D., Cor. Main and Walnut Sts., Harrisburg, Ill. (Medicine.) (1921.)
Swanson, Herbert C., 4957 N. Seely Ave., Chicago, Ill. (Paleontology.) (1929.)
Talmage, Sterling B., Ph. D., 2249 Ridge Ave., Evanston, Ill. (Geology.) (1927.)
Tamlin, Edwin, B. S., 716 W. Beecher Ave., Jacksonville, Ill. (Zoology.) (1929.)
Tammis, J. H., B. S., 207 Crescent St., Peoria, Ill. (Chemistry.) (1929.)
Tarvin, Donald B., B. Ed., Roberts, Ill. (Chemistry.) (1928.)
Taylor, David O., B. S., 1812 Hinman Ave., Evanston, Ill. (Geology.) (1929.)
Taylor, Harry, Harrisburg, Ill. (General Interest.) (1925.)
Terwilliger, George L., B. Ed., 330 College Ave., DeKalb, Ill. (Biology.) (1926.)
Teuscher, H., M. D., Boyce Thompson Institute, Yonkers, N. Y. (Botany.) (1928.)
Thomas, Gertrude M., B. Ed., 1003 N. Court St., Rockford, Ill. (Biology.) (1924.)
Thomas, Lyell J., Ph. D., 313 Nat. Hist. Bldg., University of Illinois, Urbana, Ill. (Zoology, Parasitology.) (1923.)
Thurlimann, Leota, 15065 Myrtle Ave., Harley, Ill. (General Science.) (1921.)
Thurston, Fredus A., D. D. S., 1261 E. 57th St., Chicago, Ill. (Dental Surgery.) (1921.)
Tiffany, L. Hanford, Ph. D., Ohio State University, Columbus, Ill. (Botany.) (1913.)
Tilbury, W. G., Faxton, Ill. (Biology.) (1929.)
Tillman, A. G., Ph. D., Western Illinois State Teachers' College, Macomb, Ill. (Geography.) (1929.)
Townsley, Fred D., B. A., James Millikin University, Decatur, Ill. (General Science.) (1916.)
Tunnicliff, Ruth, M. D., McCormick Memorial Institute, 637 S. Wood St., Chicago, Ill. (Medicine.) (1928.)
Turner, Lewis M., M. S., Botany Dept., University of Chicago, Chicago, Ill. (Botany.) (1925.)
Tuttle, H. H., M. D., Illinois Bank Bldg., Springfield, Ill. (Medicine.) (1925.)
Tyler, Rayen W., M. A., 204 W. University Ave., Urbana, Ill. (Physics.) (1928.)
Ulrich, Katherine, B. Ph., 305 N. Oak Park Blvd., Oak Park, Ill. (Geology, Geography, Botany.) (1921.)
Underhill, Editha, M. S., Rockford College, Rockford, Ill. (Chemistry.) (1926.)
Vance, Charles, B. Ed., Rantoul, Ill. (Physics.) (1926.)
Van Hoosen, B., M. D., 25 E. Washington St., Chicago, Ill. (Medicine.) (1927.)
Van Tuyl, Francis M., Ph. D., Colorado School of Mines, Golden, Colo. (Geology.) (1916.)
Vestal, A. G., Ph. D., Dept. of Botany, University of Illinois, Urbana, Ill. (Ecology.) (1910.)
Voss, John, B. Ed., 200 Dixon Ave., Peoria, Ill. (Biology.) (1928.)
Waechter, I. Edmund, B. S., 609 Woodland Ave., Springfield, Ill. (Metallurgy.) (1927.)
Waggoner, H. D., Ph. D., 318 Sherman Ave., Macomb, Ill. (Biology.) (1929.)
Waldo, Jennie E., B. Ed., 1204 Third Ave., Rockford, Ill. (Biology.) (1922.)
Walker, Ellis David, M. D., 5519 University Ave., Chicago, Ill. (Medicine, Biology, Agriculture.) (1921.)
Walsh, John, Box 212, Galesburg, Ill. (Water Supply.) (1921.)
Walton, A. C., Ph. D., Knox College, Galesburg, Ill. (Zoology.) (1929.)

Wanless, Harold R., Ph. D., 704 S. McCullough St., Urbana, Ill. (Geology.) (1924.)
Warbrick, John C., M. D., 306 E. 43rd St., Chicago, Ill. (Birds, Nature Study.) (1920.)
Ward, Harold B., B. S., Northwestern University, Evanston, Ill. (Geology, Geography.) (1910.)
Warner, Glen W., M. A., 7633 Calumet Ave., Chicago, Ill. (Physics.) (1927.)
Waterman, Warren G., Ph. D., Northwestern University, Evanston, Ill. (Botany.) (1914.)
Watson, F. R., Ph. D., Dept. of Physics, University of Illinois, Urbana, Ill. (Physics.) (1909.)
Watson, Josiah S., M. S., Indiana St. and Adella Ave., Joliet, Ill. (Zoology, Botany.) (1927.)
Way, Harold E., M. S., 284 N. Academy St., Galesburg, Ill. (Physics.) (1929.)
Weatherwax, Paul, Ph. D., 416 S. Dunn St., Bloomington, Ind. (Botany.) (1928.)
Weaver, George, H., M. D., Rush Medical College, Chicago, Ill. (Medicine, Bacteriology.) (1920.)
Weber, H. C., Ph. D., Westinghouse Electric Co., Pittsburgh, Pa. (Chemistry.) (1914.)
Weckel, Ada L., M. S., High School. Oak Park, Ill. (Zoology.) (1917.)
Weese, Asa Orrin. Ph. D., University of Oklahoma, Norman, Oklahoma. (Ecology.) (1924.)
Weicheit, A., M. D., Barrington, Ill. (Medicine.) (1921.)
Weinard, F. F., Ph. D., 713 W. Iowa St., Urbana, Ill. (Botany.) (1928.)
Weir, Mary E., B. Ph., Carbondale, Ill. (Geography.) (1927.)
Welker, William H., Ph. D., University of Illinois College of Medicine, 1817 W. Polk St., Chicago, Ill. (Biological Chemistry.) (1920.)
Weller, J. Marvin. Ph. D., State Geological Survey Division, Urbana, Ill. (Geology.) (1926.)
Wellman, Murrell, B. Ed., Joliet, Ill. (Physiography.) (1927.)
Wells, M. M., Ph. D., General Biological Supply House, 761-763 E. 69th Place, Chicago, Ill. (Zoology.) (1913.)
Wentworth, Edward N., M. S., Armour's Bureau of Agricultural Research and Economics, Chicago, Ill. (Genetics, Economics.) (1922.)
Wentzlemann, Gus, 280 S. Cedar St., Galesburg, Ill. (Therapy.) (1928.)
Westall, Alvene, B. Ed., 311 W. Hill St., Champaign, Ill. (Chemistry.) (1929.)
Whipple, Mrs. Velma, 613 E. Grove St., Galesburg, Ill. (Physics.) (1929.)
White, Mrs. Florence, B. A., 119 Dement St., Dixon, Ill. (Biology.) (1927.)
White, J. Kay, 904 S. Lee St., Des Plaines, Ill. (Geology.) (1926.)
Whitmore, Frank C., Ph. D., Penn. State College, State College, Pa. (Organic Chemistry.) (1921.)
Whitney, Worallo, M. A., 5743 Dorchester Ave., Chicago, Ill. (Botany.) (1910.)
Whitten, J. H., Ph. D., 7111 Normal Blvd., Chicago, Ill. (Botany.) (1917.)
Wickwire, George C., M. S., University of Illinois, Urbana, Ill. (Physiology.) (1927.)
Williams, E. H., Ph. D., 804 Michigan Ave., Urbana, Ill. (Physics.) (1925.)
Williams, Marion F., 1406 E. 55th St., Chicago, Ill. (Library Science.) (1929.)
Williams, Pauline, B. S., 226 S. 19th St., Murphysboro, Ill. (Biology.) (1926.)
Willier, Benj. H., Ph. D., University of Chicago, Chicago, Ill. (Zoology.) (1921.)
Willman, H. B., B. S., 234 Nat. Hist. Bldg., University of Illinois, Urbana, Ill. (Geology.) (1925.)
Wilson, A. H., M. S., James Millikin University, Decatur, Ill. (Botany.) (1928.)
Windsor, Mrs. P. L., B. S., 701 Michigan Ave., Urbana, Ill. (Entomology.) (1913.)
Winfield, Gerald, M. S., 615 N. Wolfe St., Baltimore, Md. (Zoology.) (1928.)
Wise, Anna Evelyn, 211 S. Center St., Joliet, Ill. (General Interest.) (1928.)
Witt, J. C., Ph. D., 5834 Stony Island Ave., Chicago, Ill. (Chemical Engineering.) (1923.)
Witzemann, Edgar J., Ph. D., Science Hall, University of Wisconsin, Madison, Wis. (Chemistry.) (1920.)
Woods, F. C., 100 N. Cherry St., Galesburg, Ill. (Physics.) (1917.)
Woods, Ruth, B. S., 713 Iowa St., Springfield, Illinois. (Botany.) (1928.)
Woodworth, M. E., Pittsfield, Ill. (Chemistry.) (1929.)
Workman, L. E., M. S., Asst. Geologist, State Geological Survey, Urbana, Ill. (Geology.) (1926.)
Worsham, Walter B., B. A., 403 W. Monroe St., Springfield, Ill. (Physics.) (1924.)
Wright, Mrs. Alice Kelsey, M. A., Southern Illinois State Teachers' College, Carbondale, Ill. (Mathematics.) (1926.)
Wright, Frank, M. D., 33 N. Wabash Ave., Chicago, Ill. (Biological Chemistry.) (1920.)
Wright, Mrs. Maurie Bailey, M. A., Beloit College, Beloit, Wis. (Botany.) (1927.)
Wynne, Ross B., B. A., 7335 Kenwood Ave., Chicago, Ill. (Botany.) (1920.)
Yoggy, I. D., B. S., 116 Bartleson St., Joliet, Ill. (Physics.) (1927.)

Young, Mrs. J. D., M. S., Windermere Hotel, 56th St. and Cornell Ave., Chicago, Ill. (Zoology.) (1911.)
Zimmerschied, Charlotte, M. A., 808 S. Illinois Ave., Carbondale, Ill. (Physics.) (1926.)
Zoller, C. H., M. D., 416 Monroe Bldg., Litchfield, Ill. (Medicine.) (1921.)

SCIENTIFIC SOCIETIES AFFILIATED WITH THE ACADEMY.

Burrill Botany Club, 204 Natural History Bldg., University of Illinois, Urbana, Ill. (1925.)
Chicago Academy of Science, Lincoln Park, Chicago, Ill. (1925.)
Illinois Association of Biol. Teachers, Mary R. Earnest, Secy., Decatur High School, Decatur, Ill. (1928.)
Illinois Association of Chem. Teachers, Rosalia M. Parr, Secy.-Treas., 321 Chemistry Bldg., Urbana, Ill. (1928.)
Illinois Nature Study Society of Elgin, 310 N. Liberty St., Elgin, Ill. (1924.)
Knox County Academy of Science, Galesburg, Ill., A. S. Galajikian, President. (1923.)
Normal Science Club, Illinois State Normal University, Normal, Ill. (1923.)
Rockford Nature Study Society, Miss F. S. Dobson, 312 N. Avon St., Rockford, Ill. (1923.)
Sigma Beta Society, Shurtleff College, Alton, Ill. (1929.)
Sigma Xi, University of Chicago Chapter, Chicago, Ill. (1925.)
Sigma Xi, University of Illinois Chapter, Urbana, Ill. (1925.)
Southern Illinois Science Club, Southern Illinois State Teachers' College, Carbondale, Ill. (1926.)
Theta Chi Delta, Alpha Chapter, Lombard College, Galesburg, Ill. (Chemistry.) (1929.)
Theta Chi Delta, Alpha Eta Chapter, Carthage College, Carthage, Ill. (Chemistry.) (1929.)

HIGH SCHOOL SCIENCE CLUBS.

Assisi Junior College, 303 Taylor St., Joliet, Ill. (1927.)
Botany Club of Joliet, care H. V. Givens, Midland Ave., Joliet, Ill. (1925.)
Boys' Science Club, High School, Galesburg, Ill. (1922.)
Danville Science Club, High School, Danville, Ill. (1923.)
Edisonian Science Club, Henry, Ill. (1926.)
Edisonian Science Club, West Chicago Community High School, Louis A. Astell, Secretary, West Chicago, Ill. (1928.)
Englewood Biology Club, Englewood High School, Englewood, Ill. (1925.)
Englewood High School General Science Club, 62nd St. and Stewart Ave., Chicago, Ill. (1924.)
Eureka Science Club, Eureka Township High School, Eureka, Ill. (1923.)
Mt. Pulaski Science Club, Pulaski Township High School, Mt. Pulaski, Ill. (1929.)
Pasteur Chemistry Club, Robinson Township High School, Robinson, Ill. (1929.)